T. Mitchell Hastings

 1896.

NOTES ON BUILDING CONSTRUCTION

PART II.

SECOND STAGE OR ADVANCED COURSE

RIVINGTON'S SERIES OF NOTES ON BUILDING CONSTRUCTION.

NOTES

ON

BUILDING CONSTRUCTION

ARRANGED TO MEET THE REQUIREMENTS OF THE SYLLABUS OF THE SCIENCE & ART DEPARTMENT OF THE COMMITTEE OF COUNCIL ON EDUCATION, SOUTH KENSINGTON

PART II.

SECOND STAGE OR ADVANCED COURSE

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PREFACE.

THESE Notes have been prepared primarily in order to assist students preparing for the examinations in Building Construction held annually under the direction of the Science and Art Department.

It is hoped that they may be found useful by others engaged in designing or erecting buildings.

The following Syllabus of the Science and Art Department has been taken as a guide in the arrangement of the Notes, and in determining the subjects to be treated upon.

SYLLABUS.[1]

Subject III.—Building Construction.

A larger number of questions will be set in the examination papers for the Elementary and Advanced stages, than the candidate will be allowed to attempt, so that he will, to a certain extent, be able to show his knowledge in such branches as he may, from circumstances, have paid special attention to.

FIRST STAGE, OR ELEMENTARY COURSE.

It is assumed that the student has already mastered the use of the following drawing instruments:—rulers, ordinary and parallel; ruling pen, compasses, with pen and pencil bow-sweeps, as well as the construction and use of simple scales, such as 1, 2, 3, or more feet to the inch, showing inches; or such as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{5}{8}$, or other frac-

[1] Taken from the Directory of the Science and Art Department of the Committee of Council on Education. Edit. 1892.

tion of full size, or of any given scale or drawing: and the meaning of such terms as plan, elevation (front, back, or side), section, sectional elevation.

He should understand the object of bond in brickwork, *i.e.* English bond, Flemish bond, or English bond with Flemish facing, and how it is attained in walls up to three bricks thick, in the following instances —viz. footings with offsets, angles of buildings, connection of external and internal walls, window and door openings with reveals and square jambs, external gauged arches (camber, segmental, and semicircular), internal discharging arches over lintels, and inverted arches.

He should know where to put wood bricks, or plugging, and their use; the construction and uses of brick corbeling, and the construction of trimmer arches in fireplaces.

He should be able to give sections and elevations to scale of the following kinds of masons' work—viz. uncoursed and coursed rubble, block in course, and ashlar, with their bond, and the proper dimensions of the stones, as to height, width of beds, and length; and of the following dressings—viz. window sills, window and door jambs, plain window and door heads, door steps, string courses, quoins, copings, common cornices, blocking courses; and of the following methods of connecting stones — viz. by cramps, dowels, joggles, and lead plugs.

He should be able to show how to join timbers by halving, lapping, notching, cogging, scarfing, fishing, and mortise and tenon; as applied to wall plates, roof timbers, floors, ceilings, and partitions.

He should be able to draw, from given dimensions, couple, collar, and king post roofs, showing the details of the framing and of the iron-work.

He should be able to draw, from given dimensions, single, double, and framed floors, with or without ceilings beneath them; showing modes of supporting, stiffening, and framing the timbers, trimming round hearths and wells of stairs; also floor coverings of boards or battens, rebated and filleted, ploughed and tongued, and laid folding, with straight or broken joints, bevelled or square heading joints.

He should be able to draw in elevation, from given dimensions, a framed partition with door openings.

He should be able to draw in elevation, and give vertical and horizontal sections of, solid door frames and window frames.

He should be able to describe, by drawings, beadings of different kinds, dovetailing, cross-grooving, rebating, plough-grooving, chamfering, rounded nosing, and housing.

He should be able to draw in elevation, and give vertical and horizontal sections of, the following doors—viz. ledged, ledged and braced, framed and braced, panelled, and the mode of putting them together, position of hinges and furniture; as well as to describe, by drawing, the following terms as applied to panelled doors—viz. square and flat, bead butt, bead flush, moulded, all on one or both sides.

He should be able to draw in elevation, and to give vertical and

horizontal sections of, the following window sashes and frames—viz. single or double hung sashes with square, bevelled, or moulded bars, and cased frames; casement sashes hung to solid frames, with method of hanging and securing in each case.

He should be able to show, in elevation and section, the lead work connected with chimneys, ridges, hips, valleys, gutters, and lead flats.

He should be able to give an elevation and section of the slating of a roof laid with duchess or countess slates on boards or battens.

He should be acquainted with the proper cross section for cast-iron beams for use in floor girders or bressummers, or as cantilevers; and be able to draw such a section in its right proportions from given dimensions of flanges.

He should be able to draw in elevation, from given dimensions and skeleton diagrams, ordinary iron roofs up to 40 feet span, showing the sections of different parts, and methods of connecting them.

SECOND STAGE, OR ADVANCED COURSE.

In addition to the subjects enumerated for the Elementary Course —in all of which questions of a more complicated nature may be set, combining work done by the different trades—the knowledge of the students will be tested under the following heads, viz.—

1st. Freehand sketches explanatory of any details of construction such as the joints of iron and wooden structures, and other parts requiring illustration on an enlarged scale. These sketches may be roughly drawn, provided they are clear and capable of being readily understood.

2d. The nature of the stresses to which the different parts of simple structures are subjected, as follows:—

In the case of beams either fixed at one or both ends, or supported or continuous, the student should know which parts of the beam are in compression and which in tension.

He should be acquainted with the best forms for struts, ties, and beams, such as floor joists, exposed to transverse stress.

He should know the difference in the strength of a girder carrying a given load at its centre, or uniformly distributed.

In the ordinary kinds of wooden or iron roof trusses, and framed structures of a similar description, he should be able to distinguish the members in compression from those in tension.

He should be able, in the case of a concentrated or uniform load upon any part of a beam supported at both ends, to ascertain the proportion of the load transmitted to each point of support.

3d. The nature, application, and characteristic peculiarities of the following materials in ordinary use for building purposes, viz.—

Bricks of different kinds in common use, York, Portland, Caen, and

Bath stones (or stones of a similar description), granite, pure lime, hydraulic lime, Portland and Roman cement, mortars, concretes, grout, asphalte, timber of different kinds in common use, cast and wrought iron, lead.

4th. Constructive details, as follows:—

The ordinary methods of timbering excavations, such as for foundations to walls, or for laying down sewers; the erection of bricklayers' and masons' scaffolding; the construction of travellers; the use of piles in foundations, hoop iron bond in brickwork, diagonal and herring-bone courses in ditto, damp-proof courses, bond timber in walls and the objections to it.

He should know how bricks are laid in hollow walls, window or door openings with splayed jambs, flues, chimneys, fireplaces, and arches up to about 20 feet span; how mortar joints are finished off, and the thickness usually allowed to them; why bricks and stones ought to be wetted before being laid.

He should be acquainted with the construction of brick ashlar walls, rubble ashlar walls, stone stairs, wooden stairs (both dog-legged and open newel), skylights, fire-proof floors (such as brick arches supported on rolled or cast-iron girders, Fox and Barrett's, and Dennett's patent concrete floors), circular and egg-shaped drains, roofs of iron or wood, for spans up to 60 feet; the fixing of architraves, linings, and skirtings to walls, shutters to windows, lath, plaster, and battening to walls, roof coverings of tiles and zinc, slate ridges and hips.

Written answers will be required to some of the questions.

EXAMINATION FOR HONOURS.

The candidate will have to furnish a design for a building, or part of a building, in accordance with given conditions; which design he will be allowed to draw out at his own home.

He will be called upon to answer in writing—illustrated by sketches, either freehand or to scale, as directed—questions on all the subjects previously enumerated for the Elementary and Advanced courses.

He must possess a more complete knowledge of building materials, their application, strength, and how to judge of their quality; and in the case of iron, of the processes of manufacture, and the points to be attended to in order to insure sound castings and good riveting.

He must be able to solve simple problems in the theory of construction, and to determine the safe dimensions of iron or wooden beams subjected to dead loads.

In ordinary roof trusses and framed structures of a similar description, he must be able to trace the stresses, brought into action by the loads, from the points of application to the points of support, as

well as to determine the nature and amount of the stresses on the different members of the truss, and, consequently, the quantity of material required in each part.

In ordinary walls and retaining walls, he must be able to ascertain the conditions necessary to stability, neglecting the strength of the mortar.

In these Notes the subjects of the above Syllabus are divided as follows :—

Part I. treats on all the points laid down as necessary for the examination in the First Stage, or Elementary Course.

Part II. contains further instruction on the same subjects, and includes all that is required by the Syllabus for the Second Stage, or Advanced Course.

Part III. furnishes full particulars regarding the materials used in building and engineering works, including all the information on this subject that is required for the Advanced Class, or for Honours.

Part IV. explains and illustrates the problems involved in the theory of construction of buildings and their application in practice, and contains all that a student can require to prepare himself for the examinations on this subject for Honours.

The art of designing buildings from given conditions must be studied in works specially devoted to that subject.

NEW AND REVISED EDITION 1891.

THE following are the principal additions and alterations that have been made in this edition.

Chapter XII. on Materials, and Chapter XIII. relating to Stresses in Structures, have been added, so that this volume may contain *all* the subjects required for the Advanced Course which have not been dealt with in Part I.

The subject of Glazing without putty has also been added; the chapter on Fire-proof Flooring has been almost re-written; also that upon Iron Roofs, and eight plates have been added to the latter, giving reduced copies of the actual contract drawings for some well-designed roofs.

The South Kensington examination papers for the Advanced Course for the last three years have been appended.

The subjects of Riveting, Centres, and Plate Girders, which are not mentioned in the Syllabus for either Part I. or Part II. of the Course, have been removed to Part I.

NOTES ON BUILDING CONSTRUCTION.

Note to Part II.

Several works on different subjects have been consulted in the preparation of these Notes, among which may be mentioned the following:—

Adams' Designing Cast and Wrought Iron Structures.
Dobson and Tarn's Guide to Measuring.
Fairbairn's Application of Iron to Buildings.
Hurst's Architectural Surveyor's Hand-Book.
Latham's Sanitary Engineering.
Latham's Wrought Iron Bridges.
Laxton's Examples of Building Construction.
Matheson's Works in Iron.
Maynard's Bridges.
Molesworth's Pocket-book of Engineering Formulæ.
Newland's Carpenter's and Joiner's Assistant.
Nicholson's Works.
Pasley's Practical Architecture (Brickwork).
Proceedings of the Institute of Civil Engineers.
Proceedings of the Royal Institute of British Architects.
Rankine's Civil Engineering.
Reed on Iron Shipbuilding.
Seddon's Builders' Work.
Stoney on Strains.
Thwaites' Factories, Workshops, and Warehouses.
Transactions of the Society of Engineers.
Tredgold's Carpentry (1870 edition); also a new, valuable, and greatly extended edition, by Mr. Hurst, C.E.
Unwin's Wrought Iron Bridges and Roofs.
Woodbury's Fire Protection of Mills.
Wray's Application of Theory to the Practice of Construction (revised by Seddon).
The Professional Journals.

The assistance derived from the above-mentioned works and others has been acknowledged, as far as possible, wherever they have been quoted or otherwise made use of.

Caution.—Some of the figures which appear to be isometrical projections are purposely distorted in order to bring important points into view.

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Science and Art Department, South Kensington, Examination Papers 1888, 1889, 1890 269-274

CHAPTER I.

BRICKWORK AND MASONRY.

(Continued from Part I.)

THIS chapter will contain brief notes on a few points connected with Brickwork and Masonry, which by the Syllabus are excluded from the Elementary Course, and were therefore hardly, if at all, touched upon in Part I.

COMPOUND WALLS.

It has already been said that uniformity of construction in walling of any description is of the first importance.

All walls must be expected to consolidate and settle down when weight comes upon them, but so long as they settle equally no injury is done; *inequality* of settlement, however slight, is dangerous, and produces unsightly cracks in the masonry.

A want of uniformity in construction leads to such results, and other evils are involved, among which is instability when exposed to the action of fire. With regard to this, Captain Shaw, the Chief of the London Fire Brigade, says, "The walls of a most pretentious and imposing building, of sufficient thickness, and apparently constructed of sound stones, are found to crack at an early stage of a fire, and perhaps to fall down altogether, and then it is discovered that they have been only a deception, having been constructed externally of stone and internally of brick."[1]

It will be as well to notice two or three forms of composite walls, in order that their structure and defects may be described.

In all compound walls the backing should have joints as nearly as possible equal in number and thickness to those in the face, so that the back and front may settle down under pressure to the same extent; if not, the joints should be in cement or quick-setting mortar, in order that they may become consolidated before any pressure comes upon them.

Evils of Facing with superior Bricks.—It is a common practice, especially in using single Flemish bond, to build the face

[1] *Fire Surveys*, by Captain Shaw, C.B.

work with better bricks, and with thinner joints, than the backing. This leads to unsound work, and should not be allowed.

In such cases, on account of the joints of the backing being thicker than those of the face work, the courses will not be of the same depth in front and back. For example, it may require eight or nine courses of the face to gain the same height as six or seven in the backing (see Fig. 1), and it is only when they happen to come to a level, as at *aa* (once in every eight courses or so), that headers can be introduced. Even the few that can thus be used are liable to be broken off by inequality of settlement, caused by the difference in the thickness of the joints.

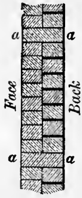

Fig. 1.

This may be partly remedied by using thinner bricks in the backing, so as to have the same number of joints in face and back; but even then the difference in thickness of the joints in facing and backing tends to cause unequal settlement, unless the work is built in very quick-setting mortar which will harden before any weight comes upon it.

A further result of this practice is that, in order to economise the more expensive face bricks, dishonest bricklayers will cut nearly all the headers in half, and use "false headers" throughout the work, so that there is a detached slice, $4\frac{1}{2}$ inches thick, on the face, having no bond whatever with the remainder of the wall.

Brick Ashlar.—This is a name given to walls with ashlar facing, backed in with brickwork.

Such constructions are liable in an aggravated degree to the evils pointed out as existing in walls built with different qualities of bricks. The coarser and more numerous joints in the brick backing are sure to consolidate to a greater extent than the few and fine joints of the ashlar, and thus tend to cause a separation of the face and backing; or, if this is prevented by bond stones, the facing will probably bulge outwards.

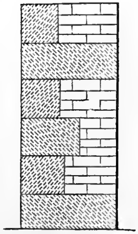
Fig. 2.

In building such work the ashlar stones should be of heights equal to an exact number of courses of the brickwork, in order that they may bond in with it; the stones should be properly square throughout, with the back joints vertical, so as to leave no vacuities between the facing and the brickwork, for these could

not be properly filled in without the expense of cutting bricks to fit the irregularities.

Rubble Ashlar consists of an ashlar stone face with rubble backing (see Fig. 3), and is subject, even to a still greater extent than brick ashlar, to the evils caused by unequal settlement.

To avoid these evils, the stones and joints of the rubble backing should, as before mentioned, be made as nearly as possible of the same thickness as those in the ashlar facing, or, if the joints are necessarily thicker, there should be fewer of them, so that the total quantity of mortar in the backing and face may be about the same. This can seldom be economically arranged in practice, but it should be remembered that the more numerous and coarser the rubble joints, the worse the construction becomes.

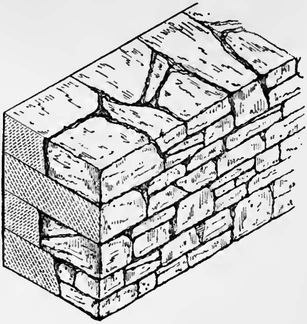

Fig. 3.

The ashlar should be bonded in with "through-stones" or "headers," as previously described; their vertical joints should be carefully dressed for some distance in from the face, and their beds should be level throughout; the back joint and sides of the tails of the stones, may, however, be left rough, the latter may even taper in plan with advantage, and they should extend into the wall for unequal distances, so as to make a good bond with the rubble, the headers from which should reach well in between the bond stones of the ashlar. Through stones may be omitted altogether, headers being inserted at intervals on each side extending about $\frac{2}{3}$ across the thickness of the wall.

Care must be taken that the stones in the ashlar facing have a depth of bed at least equal to the height of the stone. In common work the facing often consists merely of slabs of stone having not more than from 4 to 6 inches bed, with a thin scale of rubble on the opposite side, the interval being filled in with small rubbish, or by a large quantity of mortar, which has been known to bulge the wall by its hydrostatic pressure.

The ashlar facing is in all respects, except those above mentioned, built as described in the section on ashlar, Part I., and the backing may be of random rubble done in courses from 10 to 14 inches high, according to the depth of the stones in the facing.

Fig. 3 is the section of a wall 3 feet thick, with an ashlar facing composed of good substantial stone.

PREVENTION OF DAMP IN WALLS.

The importance of keeping moisture out of walls as far as possible need hardly be dilated upon.

In addition to the great importance of a dry building for sanitary reasons, it is also most necessary for good construction; dampness in the masonry soon communicates itself to the woodwork, and causes rot throughout the building, besides which, the masonry itself is not sound, the mortar, unless of good hydraulic lime, or cement, does not set, and is always liable to the attacks of frost.

To give some idea of the quantity of water that the walls of an improperly protected building may contain, and of the evil effects caused by damp, the following remarks are quoted from an official report.[1]

"In England the common bricks absorb as much as a pint or pound of water. Supposing the external walls of an ordinary cottage to be one brick thick, and to consist of 12,000 bricks, they will be capable of holding 1500 gallons or $6\frac{1}{2}$ tons of water when saturated. To evaporate this amount of water would require nearly a ton of coal, well applied. The softer and more workable stones are of various degrees of absorbency, and are often more retentive of moisture than common brick. Professor Ansted states that the facility with which sandstone absorbs water is illustrated by the quantity it contains both in its ordinary state and when saturated. He states that even granite always contains a certain percentage of water, and in the dry state is rarely without a pint and a half in every cubic foot. Sandstone, however, even that deemed fit for building purposes, may contain half a gallon per cubic foot, and loose sand at least two gallons. When water presents itself in any part of such material it readily diffuses itself by the power of capillary attraction, by which, it is observed on some walls in Paris, it ascends 32 feet from the foundations. Walls of such absorbent constructions are subject to rising wet by capillary attraction, as well as the driving wet of rain or storm. To guard against the driving wet on the coast, expensive external coverings, 'weather slates,' are used. But these do not stay the interior rising wet. This wet having to be evaporated lowers temperature. Damp walls or houses cause rheumatism, lower strength, and expose the system to other passing causes of disease."

It is a wise precaution to cover the whole surface of the ground under a dwelling with a layer of concrete, or asphalte, in order to prevent the damp and bad air out of the ground from rising into the building.[2]

[1] *Report on Dwellings in the Paris Exhibition*, by Edwin Chadwick, Esq., C.B.
[2] This is enjoined by the Model Bye-Laws of the Local Government Board.

This precaution is, however, generally omitted because it involves expense; but measures to keep the walls dry are or should be adopted in nearly all buildings intended for occupation by human beings.

The walls of a building are liable to be charged with moisture—

1. By wet rising in them from the damp earth.
2. By rain falling upon the exterior of the walls.
3. By water from the roofs or leaking gutters soaking into the tops of the walls.

Of these evils the first may be prevented by the construction of dry areas or "air-drains" and by the introduction of damp-proof courses; the second may be counteracted by impervious outer coatings or by the use of hollow walls; and the third avoided by the use of projecting eaves with proper gutters—or where parapet walls are used, by an upper damp course.

Air-Drains are narrow dry areas, 9 inches or more in width, formed around such parts of the walls of a building as are below the ground.

They prevent the earth from resting against the walls and imparting to the masonry its moisture, which, rising by capillary attraction, might cause the evils already referred to.

The outer wall of the area should rise slightly above the surrounding ground, so as to prevent the water from the surface from entering the air-drain. Arrangements should be made for keeping the area clear of vermin, for ventilating it, and also for draining off any moisture that may accumulate at the bottom.

In the section Fig. 61 is shown an air-drain 12 inches wide, having a rubble retaining wall, and being covered by flagstones built into the wall and weathered on the upper surface; of these, one here and there is removable in order to give access to the drain. The air-holes shown in the figure ensure the thorough ventilation of the drain and of the space below the floor of the building.

There are several forms of air-drains; the width of the area is often much less than that shown in the figure, and sometimes is so reduced that the arrangement simply amounts to providing a hollow wall. In other examples the outer retaining wall is curved in plan, between the piers, being concave on the inside, by which additional strength is gained and thinner walls may be used. The area is frequently covered by a small quadrant arch turned against the wall, instead of by paving.

In some cases, to avoid the expense of air-drains, the outer surface of the portion of wall below ground is rendered with cement, asphalted, or covered with a layer of slates attached to the wall.

Substitutes for properly built air-drains may be cheaply formed by placing a flagstone in an inclined position against the outside of the wall to be protected.

Wide and open areas are much more expensive, but allow a freer circulation of air, exclude damp more thoroughly, and are, on the whole, superior to air-drains.

Horizontal Damp-Proof Course.—Even where air-drains are provided, a damp-proof course should be inserted in all walls, to prevent the moisture out of the soil from rising in the masonry.

The damp-proof course should be 6 inches or more above the level of the external ground, but under the wall-plate carrying the floor-joists.

There are several forms in which a damp-proof course may be provided.

It may be of glazed pottery slabs built into the wall, as shown at D D in Fig. 6. The joints between the slabs must be left empty, or the damp will rise through them.[1]

A layer of tough asphalte about $\frac{3}{8}$ inch thick is often used instead, as at A in Fig. 7.

In buildings finished with a parapet wall, a damp-proof course should be inserted just above the flashing of the gutter, so as to prevent the wet which falls upon the top of the parapet from soaking down into the woodwork of the roof and into the walls below.

In some localities damp-proof courses are formed of asphalted felt, or with slates set in cement; these latter are rather liable to crack, and thin impervious stones, or courses of Staffordshire bricks in cement, are better. Sheet lead has been used for the same purpose, and is most efficacious, but very expensive.

Arches over vaults, or cellars under footpaths, are frequently rendered all over the extrados with asphalte or cement to prevent the penetration of wet.

Vertical Damp-Proof Course.—In addition to the precautions adopted to prevent damp out of the ground from rising in walls, it is necessary (especially when using inferior bricks or porous stones) to prevent moisture falling upon the outer face from penetrating to the interior of the wall.

The wet may be kept out of the interior of the wall by rendering the exterior surface with cement, covering it with slates fixed on battens, or with

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[1] To prevent wet which comes into the hollow space, through the outer portion of the wall, from finding its way along the top of the damp-proof course to the interior of the wall, a cement fillet may be run along the angle at the bottom of the hollow space between the top of the damp-proof course and the inner portion of the wall, and an exit should be afforded—in any case temporarily—for the water at various points by leaving openings in the brickwork. If these openings are left permanently they should be protected by gratings.

glazed tiles set in cement. Taylor's pottery facing bricks answer the same purpose.

Another plan patented by Mr. Taylor consists of overlapping slates placed vertically in the middle of the wall—the two portions of which are united by peculiar iron ties.

The Hygeian rock impervious wall-lining, patented by Mr. White of Abergavenny, consists of a vertical sheet of waterproof composition introduced into the thickness of the wall.

The wall is built up, two or three courses at a time, in two vertical slices, with about $\frac{1}{2}$-inch opening between them, the inner parts of the horizontal joints next to this opening being left empty. The melted composition being run in, fills all the openings thus left, and not only prevents the penetration of moisture but adds to the strength of the wall.

It is stated that a 9-inch wall built with the lining is stronger than an 18-inch wall built in the ordinary way.

Fig. 4, from Mr. White's circular, shows the application of his system to a water-tight tank.

This system may often be useful for parts of buildings in very damp places, but it must be remembered that walls perfectly impervious to air are, for sanitary reasons, undesirable for inhabited rooms.

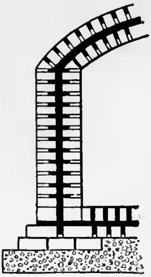


Fig. 4.

Hollow Walls not only exclude the damp, but the layer of air they contain being a non-conductor of heat tends to keep the building warm. Such walls are formed in two separate portions, standing vertically parallel to one another, and divided by a space of about 2 or 3 inches, sometimes $4\frac{1}{2}$ inches.

These two portions are generally united either by special bonding bricks or by iron cramps. There are several ways of arranging the thickness of the portions of the wall, and the consequent position of the air space.

In some cases the two portions are of equal thickness, the air space being in the centre.

Very frequently one of the portions is only $4\frac{1}{2}$ inches thick, built in brickwork in stretching bond; the other is of such thickness as may be necessary to give the whole stability.

In such a case the thin $4\frac{1}{2}$ portion is sometimes placed on the outer, and sometimes on the inner side of the wall.

Hollow Walls with the thin portion inside.—In some cases, such for instance as when the wall has a stone face, the $4\frac{1}{2}$-inch portion is necessarily on the inside, but this arrangement has many disadvantages.

In the first place, the bulk of the wall is still exposed to damp, and the moisture soaks in to within 7 or 8 inches of the interior of the building.

Again, if the wall has to carry a roof, expense is caused, as the span should be increased so as to bring the wall-plates on to the outer or substantial part of the wall, clear of the $4\frac{1}{2}$-inch lining.

This may be avoided by bridging over the air-space, so as to make the wall solid at the top, which, however, renders it liable to damp in that part.

There is an advantage in having the thick portion of the wall outside when deep reveals have to be formed for the door and window openings.

Hollow Wall with the thin portion outside.—If the $4\frac{1}{2}$-inch portion is placed outside, the damp is at once intercepted by the air-space, kept out of the greater portion of the wall, and at a considerable distance from the interior of the building.

The roof can be economically arranged so as to rest upon the interior thicker portion of the wall.

The stretching bond is, however, considered by some to be unsightly, unless made to appear like English or Flemish bond by using false headers, and, where the bricks are bad, the thin exterior portion, if liable to be attacked by frost, is in time destroyed.

Moreover, when the thin portion is outside, there is some difficulty in constructing deep reveals in a solid manner without their becoming a channel for damp across the opening. On the whole, however, the arrangement with the thin portion outside is the best.

Hollow Walls with Bonding Bricks.—Jenning's patent bonding bricks are made of vitrified pottery, and are of the shape shown in Fig. 5. These bricks are built in across the opening at

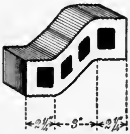


Fig. 5.

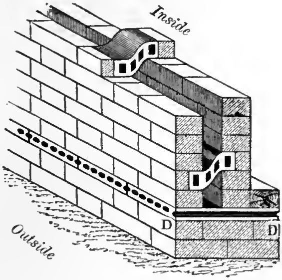


Fig. 6.
Scale, ½ inch = 1 foot.

horizontal intervals of about 2 feet 6 inches and vertical intervals of about 9 inches to 12 inches. The bricks in the several courses are placed chequer-wise, so that each is over the interval between two below.

The peculiar shape of the brick enables it to be built into the wall so that the end in the front portion is a course lower than the end in the back portion of the wall. This prevents any

moisture running along the surface of the bonding brick to the interior of the wall.

Precautions.—When building with these bricks, it is advisable to cover them temporarily with a pipe swathed in hay bands, or by a narrow strip of wood, in order to prevent the falling mortar from lodging upon them. As the wall rises, the strip is transferred in succession from each row of bonding bricks to cover the last built in.

Sizes.—The bent bonding bricks shown in Figs. 5 and 6 are made in four sizes from $7\frac{1}{2}$ inches to $13\frac{1}{2}$ inches horizontal length between their ends. Their lengths and shape are arranged so as to afford either a 3-inch or a $4\frac{1}{2}$-inch cavity, and to enter the wall either $2\frac{1}{4}$ inches at both ends—$2\frac{1}{4}$ at one end and $4\frac{1}{2}$ inches at the other—or $4\frac{1}{2}$ inches at both ends.

The bonding bricks may extend right through the thin portion of the wall, or, if this is objectionable on account of appearance, their ends may be covered by bats, as shown in the figure.

Hollow Walls with Iron Ties and Cramps.—Ties of cast iron, Figs. 8, 9, or of wrought iron, Figs. 10, 11,[1] and *x* and *y* Fig. 7, dipped when hot in tar, are frequently used instead of bonding bricks, and have the advantage of not being liable to be broken if the wall should settle unequally. On the other hand, they are subject to decay by rust, and to expansion from the same cause, which may injure the wall.

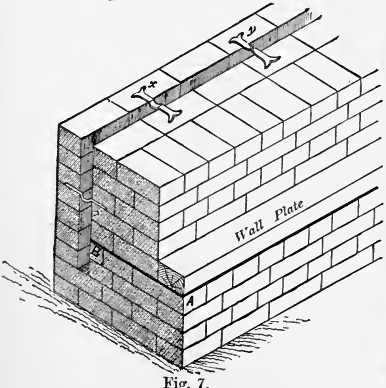


Fig. 7.
Scale, $\frac{1}{2}$ inch = 1 foot.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

The ties are about 8 inches long, $\frac{3}{4}$ inch wide, by $\frac{1}{10}$ inch thick; they are placed about 3 feet apart, horizontally, and with 9-inch vertical intervals between the rows.

Each tie is either bent or twisted in the middle, so as to stop

[1] Figs. 8 to 11 are from Messrs. Chambers, Monnery, and Co.'s advertisements.

the passage of water along its surface, and hollow iron ties possessing great strength as struts have for some time been introduced.

Cast-iron cramps are made about $\frac{1}{2}$ inch wide and $\frac{3}{16}$ thick, and somewhat similar in form to the above.

The hollow wall is often arranged to begin on the damp-proof course (see page 6), but it is better to continue the hollow for two or three courses lower, as shown in Fig. 7, so that any wet falling into the cavity may be well below the damp course. When this is done the asphalte course may be continued only across the inner thickness (AB, Fig. 7) of the wall. A covering course of brickwork is placed on the top of the air-space, which should have no communication with the outer air.

Some walls are built entirely of hollow bricks made for the purpose.

Stone walls are sometimes lined with $4\frac{1}{2}$-inch brickwork on the inside, an air flue about 2 inches wide being left between the masonry and the brickwork.

Hollow Walls built with common Bricks only.—In the absence of iron cramps or bonding bricks, hollow walls may be built with ordinary bricks placed on edge, after being dipped in boiling tar to make them as non-absorbent as possible. Every course is composed of alternate headers and stretchers, so arranged that each header comes immediately over the centre of a stretcher in the course below. The wall thus formed consists of two portions, each 3 inches thick, separated by a 3-inch space.

Another plan is to lay the bricks as in ordinary English bond, leaving a space of about $2\frac{1}{2}$ inches between the stretchers in the front and back. This makes the wall $(4\frac{1}{2} + 2\frac{1}{2} + 4\frac{1}{2}) = 11\frac{1}{2}$ inches thick, and the headers are therefore too short to reach from face to back; the deficiency is made up by inserting bats at the ends of the headers.

These and other plans adopted for building hollow walls with ordinary bricks are defective in strength as compared with the walls constructed with special bonds or cramps, and, moreover, the common bricks being porous, conduct moisture to the interior of the wall and defeat the object aimed at in making it hollow.

A better plan, in the absence of the special bonding bricks or ties, is to unite the portions of the wall by pieces of slate slab, or of dense impervious stone, used in the same way as the iron ties.

Openings in Hollow Walls.—Where the lintels of doors and windows occur in a hollow wall with a $4\frac{1}{2}$-inch exterior portion, the following arrangement may be adopted to prevent the wet which may enter the air-space from dropping upon the window or door frame.

Just above the window or door head a piece of sheet lead is built in on the inner side of the $4\frac{1}{2}$-inch exterior wall. This lead may be $4\frac{3}{4}$ inches wide, 2 inches being built into the $4\frac{1}{2}$-inch wall, $1\frac{3}{4}$ inch projecting into the air-space, and the remaining inch turned up so as to form a sort of gutter, which should be carried about 2 inches farther than the ends of the lintel each way, so as to lead the water clear of the door or window frame.

JOINTS.[1]

Mortar is used to cement the parts of a wall together, and also to prevent the fracture of the bricks or stones by insuring an even distribution of pressure, notwithstanding any irregularities in their beds.

The quantity and coarseness of the mortar that should be used will therefore decrease in proportion as the beds are more perfect; *e.g.* ashlar masonry has thinner joints than rubble, and good bricks can be set with closer joints than bad ones.

Thickness of Joints.—Excessively thick joints should be avoided when possible. They not only injure the appearance of the work, but, when the weight of the superincumbent walling comes upon them, the mortar is squeezed out, projects beyond the face of the wall, catches the rain, and leads it into the wall, rendering the work liable to injury by frost.

In good brickwork (not gauged) the joints should be about $\frac{1}{4}$ to $\frac{3}{8}$ inch thick. For ashlar masonry or gauged brickwork about $\frac{1}{8}$ to $\frac{1}{10}$ inch thick, while for rubble they vary in thickness according to the nature of the work.

The bricks or stones should be wetted so as to remove the dust, which would prevent the mortar from adhering to them, and also to prevent them from sucking the water out of the mortar. The mortar should be used stiff, and every joint well flushed, all interstices being filled with bits of brick or stone set in mortar.

Larrying is the method usually adopted for filling in the interior of very thick walls. After the bricks forming the exterior faces of a course are laid, a thick bed of soft mortar is spread between them, and the bricks for the inside of the wall are one by one pushed along in this bed until the mortar rises in the joints between them.

Grouting consists in pouring very liquid mortar over the course last laid, in order that it may run into all vacuities left by careless workmanship in not properly filling up all the internal joints with mortar. Grout is, however, a weak and objectionable form of mortar.

The joints, both of brick and of masonry, are finished so as to present a neat appearance on the face in several different ways, as in Pl. I., in which the joints are shown full size.

Flat or Flush Joints.—In these the mortar is pressed flat with the trowel, and the surface of the joint is flush with the face of the wall, as at *a* Pl. I.

Such joints are not very ornamental, but are suitable for internal surfaces to be whitewashed.

Flat Joints jointed, *b* Pl. I., are the same as those last described, except that an iron jointer is used to mark a narrow line along the centre of the joints, which improves their appearance. Sometimes both the upper and the lower edges of the joint are jointed as in *c* Pl. I.

[1] Joints in Stonework are described in Part I.

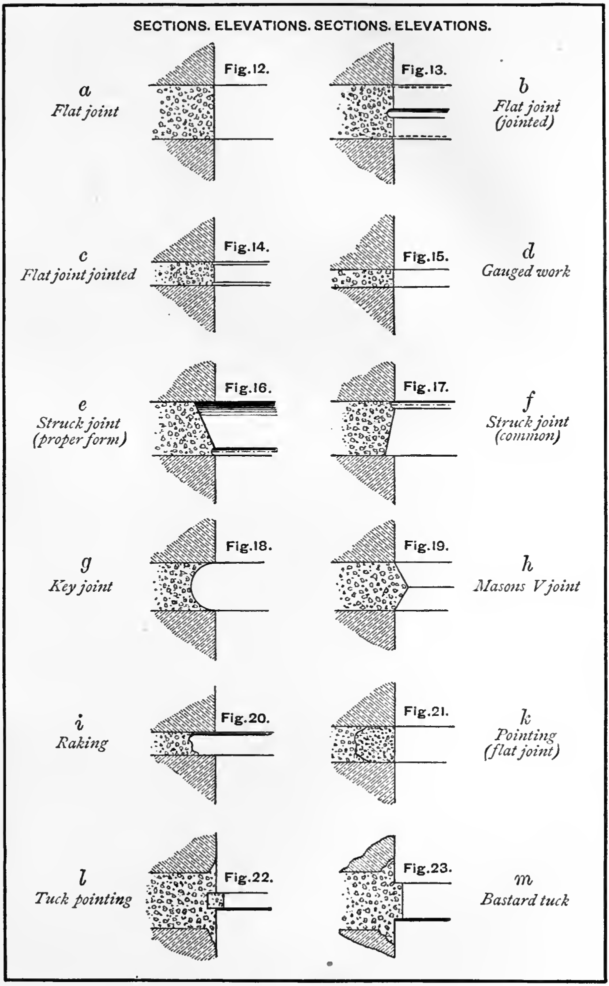

SECTIONS. ELEVATIONS. SECTIONS. ELEVATIONS.
Fig. 12.
a
Flat joint
Fig. 13.
b
Flat joint (jointed)
Fig. 14.
c
Flat joint jointed
Fig. 15.
d
Gauged work
Fig. 16.
e
Struck joint (proper form)
Fig. 17.
f
Struck joint (common)
Fig. 18.
g
Key joint
Fig. 19.
h
Masons V joint
Fig. 20.
i
Raking
Fig. 21.
k
Pointing (flat joint)
Fig. 22.
l
Tuck pointing
Fig. 23.
m
Bastard tuck

Plate I.

Gauged work (see Part I.) has very thin joints (see *d* Pl. I.) formed by dipping the bricks in white lime-putty before laying them.

Struck Joints should be formed by pressing or "striking" back the upper portion of the joint while the mortar is moist, so as to form a sloping surface which throws off the wet (see *e* Pl. I.); the lower side of the joint is cut off with the trowel to a straight edge.[1] These joints are usually struck along the *lower* edge as at *f* Pl. I.; a ledge is thus formed above which catches the rain.

Keyed Joints, *g* Pl. I., are formed by drawing a curved iron key or jointer along the centre of the flush joint, pressing it hard, so that the mortar is driven in beyond the face of the wall; a groove of curved section is thus formed, having its surface hardened by the pressure.

In some cases the moist key is dipped into ashes, which are thus rubbed into the surface of the joints.

Mason's or V Joints, *h* Pl. I., project from the face of the wall with an angular V section. With good mortar they throw off the wet, but when inferior lime is used they soon become saturated and destroyed by frost.

Raking and Pointing consists in removing the original mortar joints to a depth of about $\frac{3}{4}$ inch in from the face, *i* Pl. I., filling in with mortar, *k* Pl. I., and finishing the joints in one of the methods about to be described.

Pointing is not advisable for new work, when it can be avoided, as the joints thus formed are not so enduring as those which are finished at the time the masonry is built.

During severe frost, however, it would be useless to strike the joints at the time the work is built, for the mortar would be destroyed by the frost.

Pointing is, moreover, often resorted to when it is intended to give the work a superior appearance, and also to conceal the defects of inferior work.

In repairing old masonry or brickwork, the mortar of which has become decayed, raking out and pointing become necessary.

Both in old and new work, before pointing, the original mortar should be raked out with an iron hooked point, and the surface well wetted before the fresh mortar is applied.

Flat Joint Pointing.—The raked joints are filled in with fine mortar, and struck flat with the trowel or jointer, as at *k* Pl. I. They may be jointed as at *b* Pl. I.

Tuck Pointing, *l* Pl. I., is used chiefly for brickwork; the joints having been raked are "stopped," that is, filled up flush with mortar. This is coloured or rubbed over with a soft brick

[1] Joints so struck are sometimes called *weather joints.*

until the joints and bricks are of the same colour. A narrow groove is then cut along the centre of each joint, and the mortar is allowed to set. After this the groove is filled with pure white lime-putty, which is caused to project so as to form a narrow white ridge, the edges of which are cut off parallel so as to leave a raised white line about $\frac{1}{8}$ inch wide. This process causes inferior work to look as if it had been executed with large bricks and very fine joints; in carrying it out any defects in the work, such as irregularity of joints, are corrected by smearing over the face and striking false joints, so that badly executed work is disguised and made to present a good appearance.

Bastard Tuck Pointing, *m* Pl. I., consists in forming a ridge from $\frac{1}{4}$ to $\frac{3}{8}$ wide on the stopping itself, the edges being cut parallel and clean. There is no white line, the projecting part of the joint being of the same colour as the remainder.

Blue or Black Pointing is done with mortar mixed with ashes instead of sand.

Keying for Plaster.—When a wall is to be plastered, the joints are either raked as at *i* Pl. I. or the mortar joints are left rough and projecting—in either case to form a key for the plaster.

Vertical joints are similar to horizontal joints, but in many cases are much thinner.

VARIOUS BONDS NOT MENTIONED IN PART I.

The principal bonds used in brickwork were described in Part I., but there are one or two varieties not so commonly used which remain to be noticed.

Raking Bond is of two kinds, *Diagonal* and *Herring-bone*. In both the bricks in the interior of the wall are placed in directions oblique to the face. A course or two of raking bond is sometimes introduced at intervals in thick walls built in English bond.

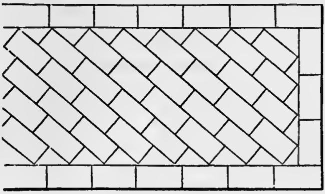
The proportion of stretchers in a brick wall diminishes according to its thickness (see Part I.) The raking courses are therefore useful in giving longitudinal strength to thick walls which are deficient in stretchers.

In both kinds of raking bond alternate courses rake in opposite directions.

Diagonal Bond.—In this the bricks (except those in the faces of the wall) are laid diagonally, at such an angle with the face that the bricks will just fit in without being cut.

A two-brick wall is the thinnest in which this can be done, and then only in the stretching courses. In thicker walls diagonal bond may be inserted in any course.

The triangular spaces at the back of the facing bricks are objectionable; it takes some trouble to cut a piece to fit them, and they are therefore frequently left empty.



DIAGONAL BOND.
Fig. 24.

HERRING-BONE BOND consists of bricks laid raking from the sides toward the centre line of the wall, as shown in Fig. 25.

This is a defective bond, for, in addition to the triangular spaces at the back of the facing bricks, there are likely to be voids, each larger than half a brick, left in the centre of the wall, unless great care be taken to have them properly filled in.

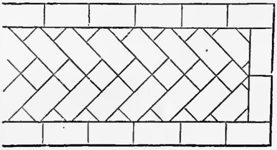


Fig. 25.

Herring-bone courses cannot be introduced at all in walls less than 3 bricks thick, and only in the stretching courses of such a wall; in thicker walls, however, this bond may be introduced in any course.

In practice this bond is rarely, if ever, adopted for walls.

Garden Bond is of two kinds—

ENGLISH GARDEN BOND consists of one course of headers to three or four courses of stretchers.[1]

FLEMISH GARDEN BOND contains in each course one header to three or four stretchers.

The object in each case is the same, to show as few headers as possible, in order to get a fair face on both sides of walls 9 inches thick, for which such bond is chiefly used.

This would not be possible if there were many headers, because ordinary bricks vary so much in length.

Bond Courses of superior construction are sometimes built into inferior walls to strengthen them.

Thus courses of brickwork may be built into walls of flints or rubble, and are called *lacing courses.*

[1] Known also as *Scotch Bond* and in some localities as *Common Bond.*—SEDDON.

Brick Piers are generally rectangular, and may be built either with or without reveals.

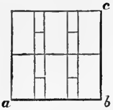


Fig. 26.

Fig. 26 is a plan of one course of a pier 18 inches square, without reveals, built in English bond.

The next course is precisely similar as regards bond, but is placed at right angles to the first, being turned round so that the side *a b* in the course coincides with *b c* in Fig. 26. The same remark applies to Figs. 27 and 28.

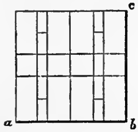


Fig. 27.

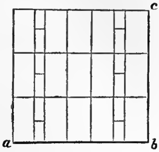


Fig. 28.

Fig. 27 is the plan of a pier $2\frac{1}{2}$ bricks square, and Fig. 28, of one 3 bricks square, both in English bond.

It will be noticed from these figures that in piers whose sides are equal in length to an even number of half-bricks (Figs. 26 and 28) all the bricks of the stretching courses are whole bricks, but when the sides are of a length equal to an uneven number of half-bricks (Fig. 27) a line of half-bricks or of headers must be introduced in each stretching course.

Bond of Walls forming Obtuse and Acute Angles.—The

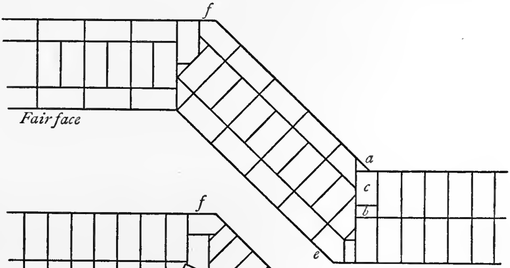


Fig. 29.

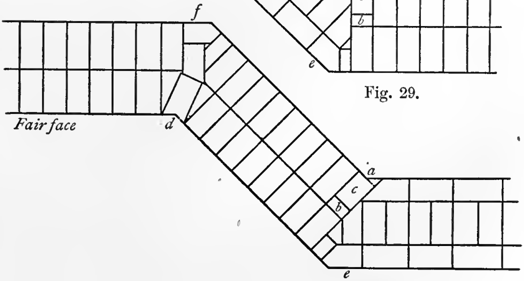


Fig. 30.

methods of arranging the bond for walls meeting at a right angle, as is most commonly the case in buildings, have been explained in Part I.; an illustration will now be given of the bond for walls meeting at an inclination greater or less than a right angle.

OBTUSE ANGLES.—Figs. 29 and 30 show two 18-inch brick walls meeting at an obtuse angle.

There are several ways of forming the bond, but the arrangement shown is a good one.

The bird's-mouths *a* and *d* and the squints *e e*, Figs. 29, 30, may be "cut and rubbed" as "axed fair," or specially moulded. The squints *f f* would be "rough cut."

To avoid cutting the bird's-mouth in the brick at the re-entering angle, the little triangular points *a* are often very improperly put in as separate pieces, in which case the bat *b* is not required, *b* and *c* being replaced by a whole brick.

ACUTE ANGLES.—In Figs. 31 and 32 two 18-inch brick walls meet at an acute angle.

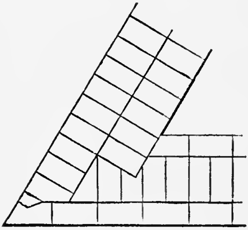


Fig. 31.

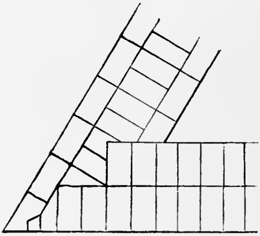


Fig. 32.

The bonds shown involve a good deal of cutting, which is inevitable to form really good work, but much of it would be omitted in ordinary building, the resulting gaps and spaces being filled in with bits of brick bedded in mortar.

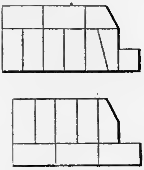
Reveals with Splayed Jambs.[1]—Splayed jambs in brickwork are weaker than square jambs, and should only be used where there is a good interval between the windows.

Figs. 33, 34, are plans of the alternate courses of a reveal with splayed jambs for a 14-inch ($1\frac{1}{2}$-brick) wall in English bond. Figs 35, 36, are plans of the same in an 18-inch (2-brick) wall.

[1] Reveals with square jambs belong to the Elementary Course (see Part I.)

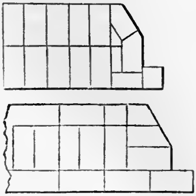
English Bond.

1½-Brick Wall.



Figs. 33, 34.

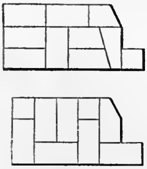
2-Brick Wall.



Figs. 35, 36.

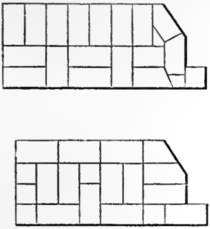
Flemish Bond.

1½-Brick Wall.



Figs. 37, 38.

2-Brick Wall.



Figs. 39, 40.

Figs. 37-40 give the same information for 14-inch and 18-inch walls in Flemish bond. There is a peculiarity in the bond of these walls which was noticed but not illustrated in Part I. It will be seen that there are no false headers in the face. Every header is a whole brick: this makes stronger work, and causes fewer splits in the wall than the ordinary single Flemish bond illustrated in Part I.

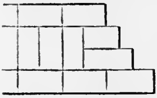


Fig. 41.

When splayed jambs are to have linings, they may be built with square offsets, as in Figs 41, 42.

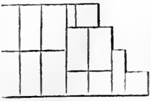


Fig. 42.

Arches.—It has been stated in Part I. that small rough arches of brickwork are generally turned in half-brick rings, and that this is especially necessary when the arch is of a quick curve, in order to avoid large joints upon the extrados.

Some authorities, however, recommend that flatter arches, especially those of larger span, should be built in 9-inch rings. This may be done in two or three different ways.

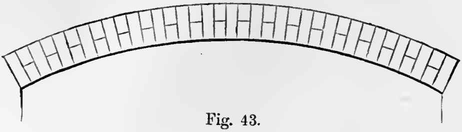


Fig. 43.

1. In English Bond.—Fig. 43 being the section, and the plan consisting of alternate courses of headers and stretchers, presenting the appearance of English bond on the soffit of the arch.

2. In Flemish Bond.—The section being like that in Fig. 43, and the soffit showing the same arrangment as the face of a wall built in Flemish bond.

3. In Heading Bond.—The ring throughout consisting of headers as in the section, Fig. 44, excepting at the ends of the arch, where three-quarter bricks are introduced to break the bond, in the same manner as is done in the face of a wall built in heading bond.

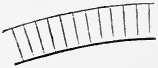


Fig. 44.

Of the above varieties the heading bond is the strongest, as the voussoirs are each in one piece and no bats are required; but it is very difficult to make neat work with such a bond, and it is therefore very seldom adopted.

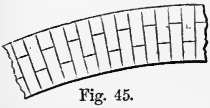


Fig. 45.

Arches $1\frac{1}{2}$ Brick thick may be built as shown in Fig. 45, which represents a section; the end elevation of the arch is the same, and the plan is like the face of a wall in English bond.

1. Arches Turned in Whole-brick Rings consist of rings like that in Fig. 44 superposed one over the other.

2. Arches in Half-brick Rings (see Fig. 46) are very commonly used, and are easily built; they should not, however, be adopted for spans exceeding 30 feet. The rings have a tendency to settle unequally; in such a case the whole weight may be thrown for a moment upon a single ring; if this is crushed, the pressure comes upon the next ring, and so on, resulting in the failure of the whole arch.

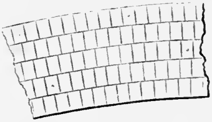


Fig. 46.

In building arches with half-brick rings it is advisable to build the undermost ring with thin joints and gradually to thicken the mortar joints as the extrados is approached; this prevents the lowest ring from settling while those above remain in position, which would cause an ugly fissure.

Arches with Bond Blocks.—To avoid the disadvantages above mentioned, arches have been built with blocks, B B, set in cement, running through their thickness at intervals, so as to form a bond right through the thickness of the arch.[1] Stone bonds may be used instead, cut to the shape of a voussoir. These bond blocks should be placed at the points where the joints of the various rings coincide: those points will be determined by the radius of curvature of the arch, the thickness of the bricks, and of the joints.

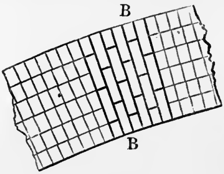


Fig. 47.

Bonding Rings in Pairs.—Another arrangement consists in introducing headers so as to unite two half-brick rings wherever the joints of two such rings happen to coincide. The rings are sometimes thus united in consecutive pairs right through the thickness of the arch.

THICK ARCHES BONDED THROUGHOUT THEIR DEPTH, as shown in Fig. 48, have sometimes been used for large spans.

The joints in the extrados are necessarily very wide, but the evil effects of this may be guarded against by using cement or quick-setting mortar, or by wedging up the joints of the outer portion with pieces of slate. In this latter case, however, the inner rings are apt to be relieved of pressure, and the stretchers are liable to drop out.

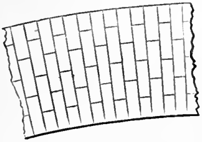


Fig. 48.

ARCHES OF LARGE SPAN, in whatever way they are bonded, should be built in good hydraulic mortar, setting moderately quickly, so that when the centres are struck the joints may be soft enough to adapt themselves to the inequalities of the bricks, and thus enable them to obtain a firm bearing. Hoop-iron bond is sometimes introduced between the rings parallel to the soffit.

In ordinary buildings, however, arches of large span are seldom required, and they need not, therefore, be further alluded to.

[1] The block B is drawn in thicker lines to make it distinct, but its joints are of the same thickness as those of the rest of the arch.

Bond Timbers were at one time extensively used to give longitudinal strength to walls, but they are injurious in many ways.

In process of time they shrink, they rot, and, in case of fire, they burn away; in either instance the whole superincumbent weight of the wall is thrown upon a small portion of it, or again, they may absorb moisture, swell, and overthrow the masonry.

Ranging Bond consists of narrow horizontal pieces built into the joints of walling parallel to one another at intervals of about 18 inches, to form grounds for battening, etc. etc. The face of the pieces projects slightly from the wall, so that the battens may be clear of the masonry.

Dry wood plugs[1] may be used instead, let into holes cut in the stones or bricks, not in the beds or joints, otherwise they may swell and disturb the wall.

It has already been stated that timber in every shape and form should be kept out of brickwork and masonry as much as possible; where it is absolutely necessary to insert it in order to form a hold for woodwork, etc., the pieces should be as small as practicable.

Hoop-iron Bond, consisting of strips of hoop-iron (about $1\frac{1}{2}$ inch broad and $\frac{1}{16}$ to $\frac{1}{20}$ inch thick), tarred and sanded, and inserted in the joints as shown in Fig. 49, is far preferable to bond timbers, and is frequently used, especially in half-brick walls.[2]

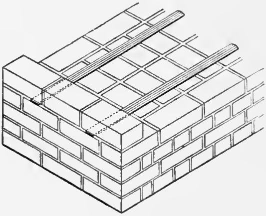


Fig. 49.

The hoop-iron should in every case be thoroughly protected from the action of the atmosphere, or it will oxidise and destroy the masonry; if used in thin walls, they should always be built in cement.

The ends of the hoop-iron should be bent so as to hook one another at the joints in the length, and at corners where two walls meet, forming an angle.

Pieces of hoop-iron are often used to make a junction where the bond of the brickwork is defective (see Part I.)

BRICK DRAINS AND SEWERS.

Brickwork is evidently not adapted for drains of very small

[1] Breeze-bricks (see Part I.) may be substituted for these.

[2] Sometimes one or two strips are used for each brick in the thickness of the wall. —Seddon, *Builders' Work.*

diameter, as there are, necessarily, very wide joints on the extrados of rings turned to a quick curve.

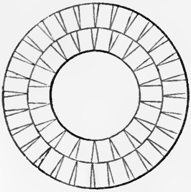


Fig. 50.

Earthenware pipes, being cheaper and preferable in every way, have in most cases long since superseded brickwork for drains of less than 18 inches or 2 feet in diameter.

Circular Drains.—When pipes are not procurable, circular drains may be constructed with bricks as shown in section Fig. 50.

This figure shows an 18-inch drain constructed with two half-brick rings, but as a rule the thickness of the brickwork need not be more than one ring, (or $4\frac{1}{2}$ inches) in sewers of less than 3 feet diameter.

Covered Drain.—Another form of brick drain consists of a semicircular inverted arch covered with a flat stone, S, the removal of which gives easy access to the drain for examination.

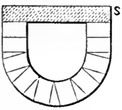


Fig. 51.

Egg-shaped Sewers may be constructed of the section shown in Fig. 52. The proportions of such sewers vary according to circumstances; but in all cases the invert, *i*, should have a quick curve (of radius not exceeding 9 inches), and the crown should be a semicircle.

The usual method of construction is to make the diameter of the invert half that of the crown, and the height of the sewer equal to **3** times the diameter of the invert.

Thus in Fig. 52—

$$hi = cf = 1. \quad gh = \tfrac{1}{2}. \quad ai = df = dk = 3.$$

The invert may be formed either of brickwork in cement, with a terra-cotta invert block, or with an invert block bedded in concrete, as shown at B in Fig. 52.

Comparative Advantages of Oval and Circular Forms.—Oval or egg-shaped sewers are the best adapted for situations where there is an intermittent flow of sewage—that is, when the quantity passing varies considerably at different times.

The reason for this is, that at the time when there is but a small quantity of sewage passing, it occupies in the narrow bottom of the egg-shaped sewer a greater depth than it would in a circular sewer of the same area of section.

This increased depth of the sewage causes it to flow with greater velocity, and thus renders the sewer more efficient.

When the flow of sewage is nearly uniform the circular sewer may be adopted, and will be found stronger and cheaper than the other.

Bricks for sewers should be of the hardest possible description, and laid

in hydraulic mortar. Even the best bricks will be gradually destroyed by the sewage.

The inverts especially require to be of hard lasting material with a smooth surface, so as to resist as little as possible the passage of the sewage matter passing over them. They should, therefore, be formed with a smooth terra-cotta or fireclay invert block, as shown in Fig. 52, or built with glazed or very smooth bricks. Bricks "purpose-moulded" to the radii make the best sewers; but where they cannot be obtained, blocks are sometimes formed with common bricks placed in frames, grouted and formed into a solid mass with cement.

When sewers are constructed in a porous soil, the invert should be very carefully built, and a lining of puddle clay placed outside the sewer, so as to render it water-tight to half its vertical depth.

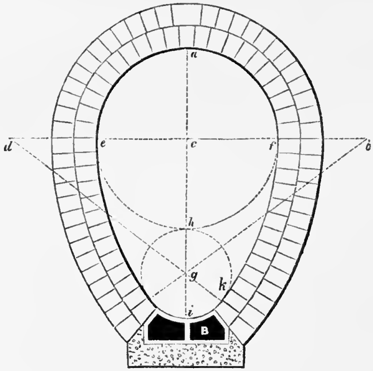


Fig. 52.

Great care should be taken in filling in over sewers, so that large clods or masses of earth may not be allowed to fall upon the brickwork and injure it.

Sewers are frequently built in concrete either alone or combined with brickwork.

When concrete is used by itself it is sometimes rammed into a trench round a mould of the section intended for the sewer, so that the sewer consists of a rectangular block of concrete containing a circular or egg-shaped tunnel.

In many cases, however, the concrete is lined with brickwork, and sometimes the lower part only of an egg-shaped sewer is built in brickwork, the upper portion being finished with concrete rammed in over a centre.

Concrete is also much used for the foundations of sewers in unfavourable positions; the lower half of the sewer is imbedded in a block of concrete, which is made of a width and thickness suitable to the nature of the ground.

Sewers are also built up of hollow terra-cotta segment blocks, which fit into one another with groove and tongue joints.

The construction of drains with stoneware pipes, and of sewers

in concrete, or in segment blocks, will not be further noticed, as the subject does not fall within the limits of this Course.

CHIMNEYS.

The fireplaces in a house frequently stand one immediately over the other, and each chimney flue[1] from the lower rooms has in consequence to be carried to one side or the other to avoid the fireplaces above it.

Arrangement of Flues.—Flues from the lower stories are therefore necessarily curved, but not those from the attics; a curve is, however, considered advisable in all flues, to prevent rain or sleet from beating vertically on to the fire, and to stop down-draughts of cold air. This curve should be sufficient to prevent daylight from being seen when looking up the flue.

The funnel, or opening above the fireplace, is gathered over (see page 29), so as to be contracted to the size of flue required.

Fireplaces generally require more depth than can be provided in the thickness of the wall; this necessitates a projection to contain the fireplace and flues called the *chimney breast*. Sometimes this projection is on the back of the wall, in which case it gives more space and a more convenient shape to the room. When on the outer wall of a house it may be made an ornamental feature.

Every fireplace should have a distinct flue to itself; if the flues of two fireplaces communicate, and only one fire be lighted, it will draw air from the other fireplace, and smoke; moreover, its own smoke may enter any other room the fireplace of which is connected with the same flue.

The air heated by the fire is rarefied, rendered lighter, and ascends the flue, drawing the smoke with it, whilst cold air rushes into its place from below.

Hence the throat or lower opening of the flue should be small, so that no air may pass through it without first coming into contact with the fire and being thoroughly warmed.

The flue should not be larger than is necessary for conveying the smoke and heated air; if too large, it will smoke in certain winds.

With regard to the proper size for flues there are great differences of opinion. The size should vary according to the circumstances of different cases; but generally speaking a flue 9 inches square is sufficient to carry off the smoke from very small grates, a flue 14 inches × 9 inches for ordinary fireplaces, and a flue 14 inches × 14 inches for large kitchen ranges.

The smaller the flue, and the greater the height, the more rapid the draught and the less likely the chimney to smoke, provided that sufficient air is supplied and that the flue is large enough to carry off the smoke.

[1] Sc. *Vents.*

The flue should change its direction by gradual curves and contain no sharp angles, otherwise soot accumulates and makes it smoke. The Building Act requires that if any angle is necessarily less than 130° an iron soot-door should be provided at the bend, so that the soot may be removed (see S, Fig. 61).

Much depends upon the height of a flue, the shortest, *i.e.* those from upper rooms, or in low buildings, being most liable to smoke.

The air should pass through or very near the fire.

Thus a high opening above the fire is bad, as it admits cold air, which gets up the flue without being heated, and cools the rising warm air.

The fireplace should, therefore, be not much higher than the grate.

All walls about chimneys should be well built, and so should the "withes" or partitions between flues, as cold air may penetrate badly-built walls from the outside, or from an unused flue cold air may get into one in use, thus cooling the heated air and causing the chimney to smoke.

If openings are left in the withes, the smoke from a flue in use may penetrate another, and from it enter a room in which the fire is not burning.

Arrangement of Flues.—The width of the chimney breast for each room of a high building must be arrived at by drawing the plan of the fireplace of each room, including the flues from the fireplaces of the rooms below; they can be arranged in plan in such a form as may be most convenient for the chimney stack.

A very common practice is to build the fireplaces of adjacent rooms or houses back to back, in which case the arrangement on each side of the wall is exactly the same.

The plan of bringing a number of flues into a "stack" is economical, and tends to preserve an equal temperature in them.

First Illustration of Arrangement of Flues.—Figs. 53, 54, are respectively longitudinal and cross-sections of the fireplaces and flues in the wall between two 5-storied buildings.

The dotted lines in Fig. 54 show the direction of the flues of the fireplaces on the other side of the wall.

The remaining figures on page 27 show the plan of the chimney breasts on the level of each floor.

The weight upon the chimney breasts should be spread over a greater area by introducing footings,[1] as shown in Figs. 53, 54.

In some cases the same object is attained by turning an invert arch between the chimney breasts under the fireplace.

In order to economise the brickwork, and to leave as much

[1] Sc. *Coddings.*

interior space in the building as possible, the part of the chimney breast in each room is generally made of the minimum width that is absolutely necessary to contain the flues at that point.

Thus it will be seen that the chimney breasts on floors I K and G H are made narrower than those above them, because they contain fewer flues. The extra width required for the flues in the chimney breast on the other floors is gained by corbelling out as shown at *t t*. The projections in the brickwork are concealed under the floor and by the cornice of the ceiling below.

Sometimes one side of the chimney breast is made narrower than the other; thus the side x (Fig. 59) might be made narrower than y, and w narrower than z (Fig. 57), for in each case the chimney breast on the left contains one flue less than that on the right. This causes an unsymmetrical appearance, but is often done even in superior buildings.

The whole of the external walls, both of chimney breasts and shafts, are generally made half a brick or only $4\frac{1}{2}$ inches thick.

It is safer, however, to make the front and outside wall of the chimney breasts 9 inches thick, especially when they are in contact with woodwork, such as skirtings, roof-timbers, etc.

Again, even when this is done, the outside wall of the chimney shaft itself is often reduced to half a brick directly it has passed through the roof. It is better, however, to keep the external walls of the shaft 9 inches thick throughout (as dotted at S S in Fig. 53), for the reasons stated at p. 32.

Second Illustration of Arrangement of Flues.—It is frequently necessary, for the sake of appearance, to place the chimney in a symmetrical position, such as the centre of the roof. To this end, and also in order to avoid a multiplicity of chimney shafts, the flues have to be collected from opposite sides of the house into a central stack.

Fig. 61 shows an example of this. The flues from the rooms A, B, C, and E, converge towards a central stack, the space between the chimney breasts of the upper rooms being bridged by an arch W, over which the flues are carried; the brickwork forming the upper wall of the flue is racked back as shown, leaving only thickness sufficient for safety above the flues.

The chimney breast of the room C cannot be carried down to the foundation, as it would interfere with the folding-doors in the room below. It is therefore supported by courses corbelled out into the room from the wall, as shown in dotted lines.

It will be noticed that the chimney breast of the room A is nearer the outer wall than that of the room below; in order to avoid widening the chimney breast below, the upper and outer chimney breast p is supported by courses corbelled over to one side as dotted. The corbelling is concealed by being carried out within the floor.

The projecting part of the upper chimney breast might be supported by turning an arch, as shown by the dotted line X, and this is a construction often adopted.

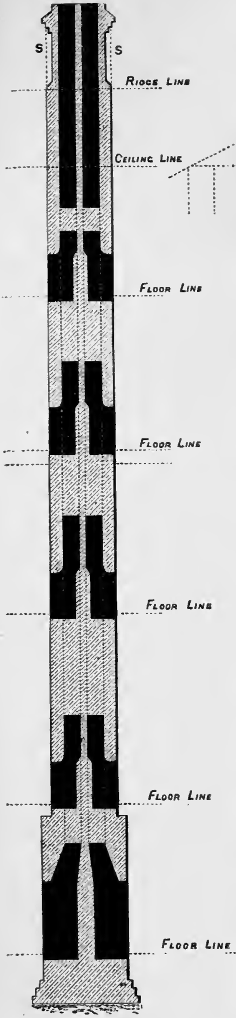


Fig. 53.

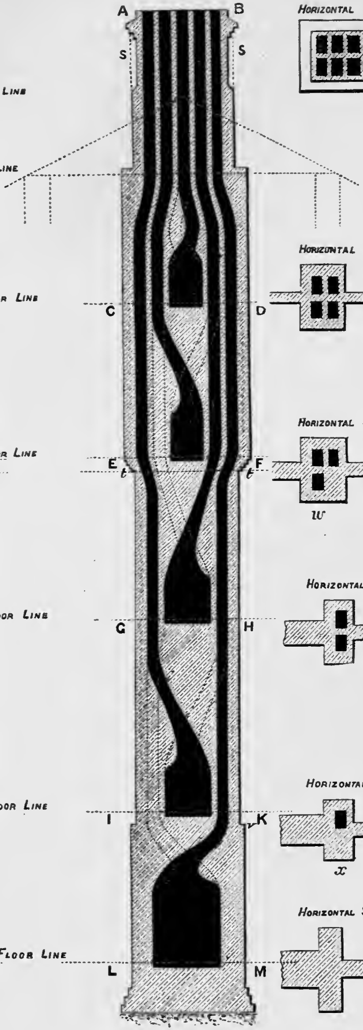


Fig. 54.

Scale, $\frac{1}{10}$ inch = 1 foot.

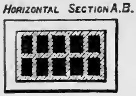


Fig. 55.

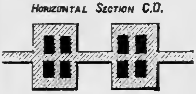


Fig. 56.

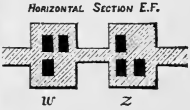


Fig. 57.

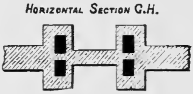


Fig. 58.

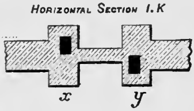


Fig. 59.

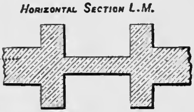


Fig. 60.

Fig. 62.

Fig. 61.

Scale, $\frac{1}{10}$ inch = 1 foot.

This Figure is the section of an ordinary dwelling-house taken on this side of the flue from E, and is intended to show two or three different arrangements of flues. It also illustrates the remarks made in Part I. as to the increase of roofing required when the wall plates are placed in the middle of the thickness of the walls. The whole surface of the ground may, with advantage, be covered by a layer of concrete, as described at p. 4.

It will be seen that the flue from the room E is carried vertically up in the thickness of the outer wall as high nearly as the ceiling of room C, then over an arch covering the recess between the chimney breast and the outer wall.

The portion of flue in the thickness of the outer wall is rather apt to be cold and to check the draught, and the construction might in this case be avoided by carrying the flue across the corner of the party wall of room D, and up the left chimney breast *s* (which would have to be widened to receive it) of the room C, above.

The flues in this illustration are supposed to be formed with circular earthenware pipes [1] of 9 inches diameter, shown in plan in Fig. 62.

The external walls are here shown only $4\frac{1}{2}$ inches thick, because the thickness of the flue-pipe itself affords a great protection and renders it unnecessary to make the brickwork so thick as it should be round pargetted flues.

Chimney Shafts. [2]—At the ceiling of the highest room the chimney breast is reduced in size to the chimney shaft of a width just sufficient to contain the flues. This shaft should be carried well above the roof, higher if possible than adjacent roofs or buildings, which are apt to cause eddies or down-draughts and make the chimneys smoke.

Chimney Caps.—A few of the upper courses of high chimney shafts are generally made to project, and should be built in cement to serve as a protection from the weather.

The cap is frequently made ornamental by bricks, placed anglewise, etc., in a similar manner to the brick cornices and coping referred to in Part I. Stone caps are also used for brick as well as for stone chimneys.

Fireplaces.—Jambs of fireplaces are built in the same manner as brick walls. The chimney breasts should be carefully founded, resting upon footings, or supported by corbels where necessary.

In order to form the throat of the chimney, the courses are "gathered" over, each projecting $1\frac{1}{8}$ inch or so over the last, until the opening is narrowed to the required dimensions. The exact projection depends of course upon the curve required. The narrowest part or throat should be immediately over the centre of the fireplace. Above the throat, the flue ascends vertically for a short distance, then gathers again to the right or left, as shown in Fig. 63.

The projecting corners of the offsets are cut off, and where the flue recedes the re-entering angles are sometimes filled up with bits of brick, or by the rendering of the flue.

[1] Sc. *Vent-linings.* [2] Sc. *Stalks.*

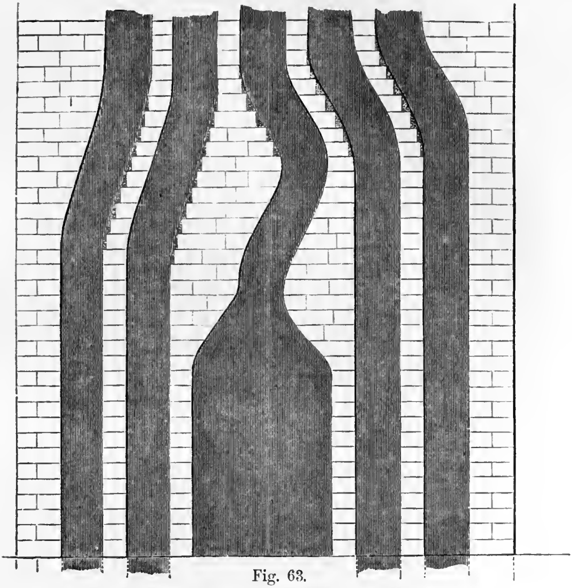
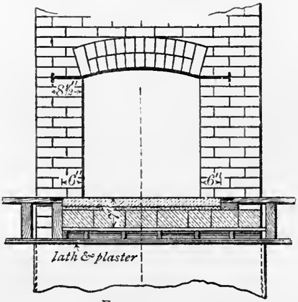
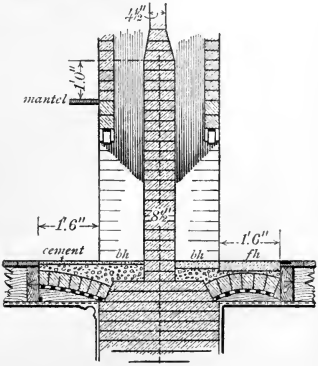


Fig. 63.



ELEVATION

Fig. 64.



SECTION

Fig. 65.

In consequence of the number of bats necessary in such work, the bond cannot be laid down beforehand, but must be left a good deal to the bricklayer.

Fig. 63 is an enlarged section of the flues contained in the chimney breast just above the floor, C D, in Fig. 54. It shows the method of gathering over for the flue of a small fireplace, and also the arrangement of the bricks in forming the withes, etc., for the flues from the stories below.

Fig. 64 is an elevation, and Fig. 65 a section, of a fireplace, showing the rough arch supported by a "*turning bar*,"[1] T T, of which a sketch is given in Fig. 66. The bricks next to the skew-backs are often laid as headers.

This bar is from $\frac{1}{2}$ to $\frac{3}{4}$ inch thick, and about 3 inches wide. It has a bearing of $4\frac{1}{2}$ inches on each jamb, and beyond the bearing portions, ends about 3 inches long. These ends are sometimes split longitudinally, and *corked*,[2] *i.e.* turned in opposite directions, up and down, as shown in Fig. 66. Very frequently the ends are turned either up or down without being split, and this is a better plan than that shown, for it renders it unnecessary to cut bricks.

Fig. 66.

The bar is curved to fit the soffit of the arch, and in order to prevent it from straightening under the thrust a small bolt is sometimes passed through it and secured to a plate on the crown of the arch.

Flat turning bars have been advocated as tending to draw the jambs together instead of thrusting them out, but they are seldom if ever adopted.

The interior of the jambs of chimney breasts should always be filled in solid.

Hearths are stone flags about $2\frac{1}{2}$ inches thick, placed so as to catch the droppings from the grate. The *back hearth, bh* Fig. 65, covers the space between the jambs of the chimney breast.[3] The *front hearth, fh*, rests upon the trimmer arch described in Part I.

Bond of Chimney Shafts.—It has already been mentioned that the external walls of chimneys should be 9 inches thick, at least until the shaft has passed through the roof; they are better if built in cement.

[1] Or Chimney-bar. [2] Or Caulked.

[3] Solid concrete hearths are frequently used instead of stone hearths on brick trimmer arches.

Such a thickness is almost necessary for safety within the building, where the woodwork of the roof and skirtings is frequently brought up against the chimney.

It is, moreover, an advantage to have a thick wall round the chimney shaft, even in the open air, as it tends to keep the flue warm. A thin wall is soon partially destroyed by the weather, and admits cold air to the flue, causing it to smoke.

WHOLE-BRICK EXTERNAL WALLS, ENGLISH BOND.—Figs. 67, 68, give horizontal sections of two courses of the chimney in Fig. 54, just before it emerges from the roof. It has an exterior wall 9 inches thick built in English bond.

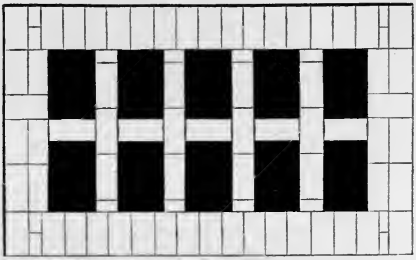
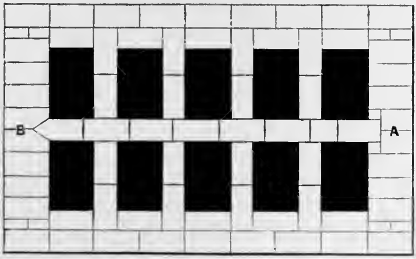


Fig. 67.



Chimney. Whole-Brick external walls. English Bond.

Fig 68.

It will be seen that the cross withes are well bonded into the external walls in alternate courses, and the longitudinal withe may also be bonded in either by cutting bricks as at A, or by mitreing as at B.

HALF-BRICK EXTERNAL WALLS, ENGLISH BOND.—In ordinary buildings the external walls of chimneys and chimney breasts

are, for economy, made only half a brick thick throughout, both inside the building and above the roof. Examples of the necessary bond are therefore shown in Figs. 69, 70, though such thin external walls are objectionable for the reasons already stated.

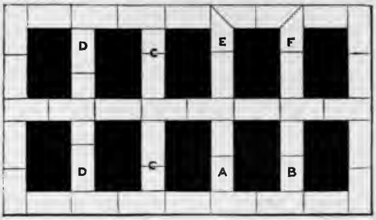
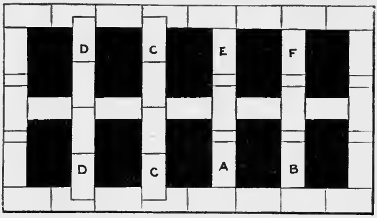


Fig. 69.



Chimney. Half-brick external walls. Stretching Bond.
Fig. 70.

Stretching Bond.—These $4\frac{1}{2}$-inch external walls are sometimes built in stretching bond; such a bond, however, carried out in the ordinary manner, leaves the cross withes quite detached from the side walls, as are the withes A B in Fig. 70.

This may, however, be avoided by causing the withes in alternate courses to penetrate the side walls to the depth of $\frac{1}{4}$ brick or $2\frac{1}{4}$ inches, as shown in withes C C, D D, Fig. 70, or by cutting the bricks forming the ends of the withes to a mitre, as at E F, Fig. 69, so as to fit the adjacent bricks in the external wall, which are similarly cut.

In both these arrangements the bricks are not allowed to show on the face of the external wall, as headers would interfere with the appearance of the stretching bond.

Half-Brick External Walls, Flemish Bond.—The external walls of chimneys may very conveniently be built in Flemish bond as shown in Figs. 71, 72. It will be noticed that there is no elaborate cutting of bricks, the bond is perfectly symmetrical, and the withes are admirably united with the external walls.

If the flues at one end were required to be 14 inches square, as for a

very large kitchen chimney, $\frac{3}{4}$ bricks would be used instead of *c c*, and half bricks or false headers inserted at *h h*.

The exact arrangement of bond in a chimney must depend upon the size, shape, diameter, and arrangement of the flues, the thickness of the outer walls, the bond adopted in the building, and other particulars depending upon circumstances.

It would of course be impossible to illustrate even a very small portion of the various arrangements required by different combinations of the above particulars.

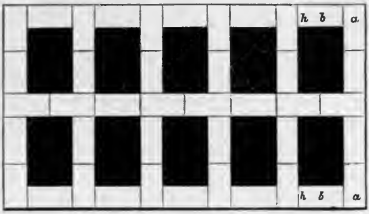
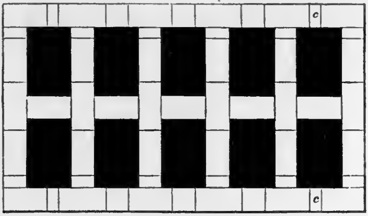


Fig. 71.



Chimney. Half-brick external walls. Flemish Bond.

Fig. 72.

Further examples cannot here be given, but it will be good practice to the student to draw for himself the bonds best adapted for chimneys of different forms and arrangements, in doing which it is hoped that he will find the above illustrations a useful guide.

Stone Chimneys.—Chimney breasts in stone buildings are very often built with bricks, which are better adapted than stone for forming the thin withes and walls required, and generally less expensive than sound masonry.

The chimney breasts and flues are, however, frequently built in rubble.

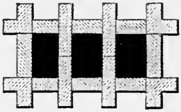
When the chimney passes above the roof it is of course necessary that, for the sake of appearance, it should be of the same material as the walls of the building generally.

Chimneys in rubble are built in a very similar way to those in brickwork; those of cut stone or ashlar are very varied in form and design.

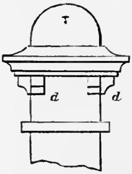
Figs. 73 to 75 show the plan and elevations of a chimney in cut stone, of a form frequently used.

The cap is supported by blocks, *d d*, and surmounted by semicircular " terminals," T, T, which are intended to prevent down-draughts, and to protect each flue from the action of those adjacent to it.

Fig. 73.

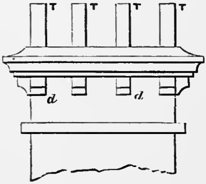


Plan.



End Elevation.

Fig. 75.



Side Elevation.

Fig. 74.

Chimney Flues, especially those in masonry, are frequently formed with earthenware pipes, which afford but little resistance to the smoke, are free from the objectionable corners of brick flues, do not collect the soot, and are easily kept of uniform section throughout; on the other hand, if the internal surface is too smooth, the soot is apt to collect and fall in lumps.

Rendering.—The flues may be rendered inside with Portland cement.

Pargetting.—The ordinary method is, however, to plaster the inside of the flue over with a mixture of one part of lime with three of cow dung; this forms a tough lining with a smooth surface, and not so liable to crack as ordinary mortar.

Coring.—While a chimney flue is being built, it is advisable to keep within it a bundle of rags or shavings called a "sweep," in order to prevent mortar from falling upon its sides; and after the flue is finished, a wire brush or core should be passed through it to clear away small irregularities, and to detect any obstruction that there may be in the flue.

Chimney Pots[1] are frequently placed over flues, to prevent the eddy of wind that would be caused by a flat surface at the top of the chimney.

[1] Sc. *Chimney cans.*

CHAPTER II.

TIMBER ROOFS.

(Continued from Part I.)

THE king-post roof and simpler forms described in Part I., are adapted for spans up to 30 feet.

This Advanced Course includes the trusses ordinarily used for spans of from 40 to 60 feet.

Gothic and other roofs adapted for special styles of architecture, or for particular situations, will not be referred to.

Trusses involving the use of curved or built-up beams are also excluded.

N.B.—In all the figures illustrating timber roofs, the distinctive letters for different parts are as follows :—

Angle Tie	*a*	Pole Plate	*pp*
Battens	*b*	Princess Post	*PP*
Binders	*Bi*	Purlin	*P*
Blocking Course	*Bc*	Rafters, Principal	*PR*
Boarding	*B*	,, Common	*CR*
Ceiling Joists	*Cj*	,, Jack	*JR*
Cleats	*C*	Ridge	*r*
Collar Tie	*CT*	Soffit	*fs*
Cornice	*c*	Struts	*S*
Fascia	*F*	Slates	*s*
Gutter	*G*	Straining Beam	*SB*
Gutter-bearer	*gb*	,, Sill	*SS*
Gutter-plate	*gp*	Templates (wall)	*wt*
King Bolt	*KB*	Tie Beam	*T*
,, Post	*KP*	Tilting Fillet	*tf*
Queen Bolt	*QB*	,, Batten	*tb*
,, Post	*QP*	Truss (Principal)	*TP*
Parapet Wall	*PW*	Wall Plates	*wp*

King and Queen Post Roofs.—King-post trusses will do very well for roofs up to about 30 feet span, but for wider roofs it is found that the tie beam requires support at more than the one central point; additional vertical ties, called queen posts, have therefore to be introduced, as at QP, QP, Fig. 76.

The common rafters being longer, require support at more than

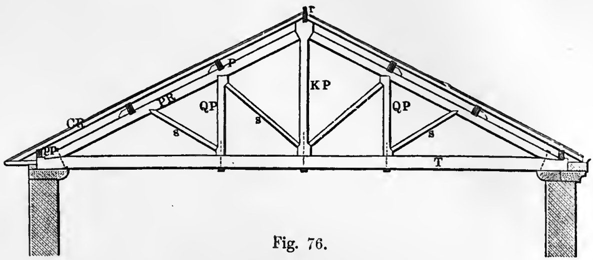


Fig. 76.

one point, two purlins are therefore introduced on each side of the roof.

Queen-Post Roof with King Bolts.—This excellent construction is shown in Fig. 96, p. 49.

When a flat top is not required, purlins with common rafters running down the slope of the roof are adopted, as in Fig. 76, and the apex of the roof finished as there shown.

Queen-Post Roofs.—When rooms have to be formed in the roof, and frequently besides, the king post is omitted, in which case, to prevent the heads of the queen posts from being forced inwards, a straining beam is placed between them, as shown at SB in Fig. 77, and their feet are kept apart by a straining sill, SS.

This form of roof is well adapted for spans of from 30 to 45 feet.

The ends of the straining beam sometimes receive additional support from cleats, as at C, secured to the queen posts. The strap above C is omitted in the figure in order to show the joint.

Roof with Queen Posts and Princesses.—In roofs of a greater span than 45 feet, the tie beam requires to be upheld at more than two intermediate points.

The extra support necessary is furnished by the introduction of additional suspending posts, PP, known as *Princesses.*

Such a construction as that shown in Fig. 80 may be used for spans between 45 and 60 feet.

In roofs of above 50 feet span the straining beam between the heads of the queen posts is so long that it would sag without support, and this may be afforded by means of a small king tie, suspended from the junction of the principal rafters, which are prolonged above the straining beam, as dotted in the figure.

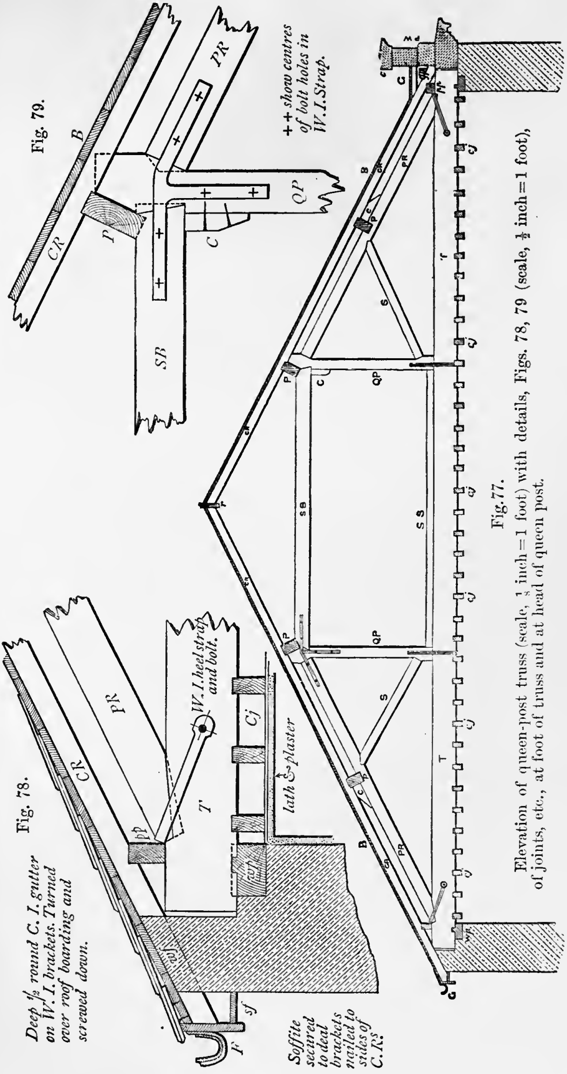


Fig. 77.

Elevation of queen-post truss (scale, $\frac{1}{8}$ inch = 1 foot) with details, Figs. 78, 79 (scale, $\frac{1}{2}$ inch = 1 foot), of joints, etc., at foot of truss and at head of queen post.

In a roof of this kind the space between the queen posts affords convenient accommodation.

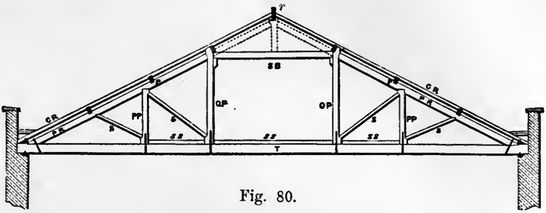


Fig. 80.

Roofs of Spans greater than 60 Feet.—The consideration of such roofs does not fall strictly within the limits of this course, and in these days they would generally be constructed of iron; it will be sufficient, therefore, to give one or two skeleton examples of old timber roofs of large span, before dismissing the subject.

In these figures the lines all represent timber in scantling, framed and put together in a similar way to the members of the trusses depicted in Figs. 76-80.

Fig. 81 nearly resembles the roof of the old Birmingham

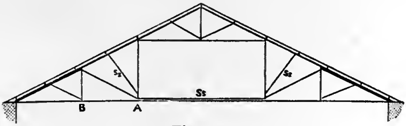


Fig. 81.

Theatre, and is recommended by Tredgold as a good truss for roofs of from 75 to 90 feet span.

In this case the triangular portion above the straining beam, being of considerable dimensions, is formed into a regular king-post truss.

The length of rafter between the queen post and princess being so great as to require support, this is afforded by means of a second strut, S_2.

In this roof the straining sill, SS, was keyed and bolted to the tie beam, and the tie beam was scarfed between A and B.

The scantlings adapted for the trusses shown in Figs. 77-81 are given at pages 51 and 52.

Fig. 82 shows one of the principal trusses of the old roof of Exeter Hall.

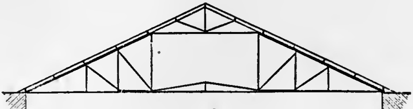


Fig. 82.

This truss is of 76 feet span, and includes a second set of princesses.

In other respects it is similar to the roof last mentioned, except that the straining sill is trussed as described at page 42.

The scantlings of this roof were as follows:—

	Inches.		Inches.
Tie beam	14½ × 7½	Struts	7½ × 7½
Principal rafters { long	8½ × 7½	Apex { king posts (oak)	6 × 7½
Principal rafters { short	14 × 7½	Apex { struts	6 × 7½
These extended only as far as the head of the queen post.		Straining sill	7½ × 7½
		Common rafters	5 × 2¼
Straining or collar beam	14 × 7½	Hip rafters	10 × 2½
Queen posts (oak)	8½ × 7½	Ridge piece	8 × 3½
Princesses	12 × 4½	Pole plates	12 × 4
do. outer set	10 × 4½	Wall plates	13½ × 6

Fig. 83 shows a similar form of roof, but with the apex re-

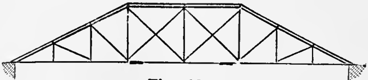


Fig. 83.

moved, and a lead flat substituted, the central portion, which carries the flat, being strengthened by the introduction of a king post and cross bracing.

Roofs composed of Wood and Iron for Spans of more than 40 Feet.—As already stated in Part I., the chief use of wrought iron in composite roofs is as a substitute for the wooden posts or suspending pieces which uphold the tie beam.

Cast iron is also used, in the form of shoes, heads, etc., for receiving and connecting the members of the truss.

It is not considered worth while to give any illustrations of composite roofs of wide span, as they are similar in principle to those illustrated in Part I., and have not been much used since the introduction of iron roofs.

PARTS OF A QUEEN-POST ROOF.

The parts common to all ordinary roofs, such as tie beams, rafters, wall plates, purlins, ridges, gutters, etc., have already been considered in Part I., and it remains only to give a description of those peculiar to queen-post roofs.

Queen Posts.—These have, between them, to carry about $\frac{2}{3}$ the weight of the tie beam, together with that of the ceiling, if any, suspended therefrom, and they frequently have to support additional loads brought upon the tie beam by the occupation of the space between the queen posts as a garret.

The heads of the queen posts are kept apart by a "straining beam," SB (Fig. 77), and the feet are tenoned into the tie beam and prevented from moving inwards by a "straining sill," SS.

The feet of the queen posts are sometimes secured by being housed on their inner sides into the tie beam, in which case the straining sill may be dispensed with.

Straining Beam.—The object of this beam has just been mentioned—its ends are supported by being housed and tenoned into the heads of the queen posts, additional security being generally afforded by cleats, C, nailed to the posts as shown.

When the straining beam is of considerable length it is sometimes supported in the centre by struts inclining inwards from the feet of the queen posts, as in Fig. 96, p. 49.

In that figure it is shown as supporting a lead flat, in which case it may with advantage be made thicker in the centre than at the ends, so as to strengthen the beam, and to give the lead a slight slope outwards.

Straining Sill.—This is generally merely a piece of scantling lying on the tie beam, and butting against the feet of the queen posts (Fig. 77, p. 39).

The straining sill is sometimes bolted and keyed to the tie beam in the manner explained under Built up Beams in Part. I.

It may, however, be arranged, as shown in Fig. 82, so as to form a truss and give support to the centre part of the tie beam.

In a roof with princess posts, straining sills may advantageously be introduced between the feet of the queens and princesses.

Binders, marked *Bi,* are shown in Fig. 96 framed in between the tie beams. This is sometimes a convenient arrangement for

stiffening the roof. It may also be adopted when the principals are widely spaced, in order to afford a shorter bearing for the ceiling joists.

Purlin Roofs.—When a long building is divided into rooms of moderate length by partition walls running across it, as shown in Fig. 84, the walls themselves play the part of the principals and carry the purlins, these latter supporting the rafters as usual.

If the purlins have to be of such a length that their scantling would be inconveniently large, they may with advantage be constructed in the form of trusses.

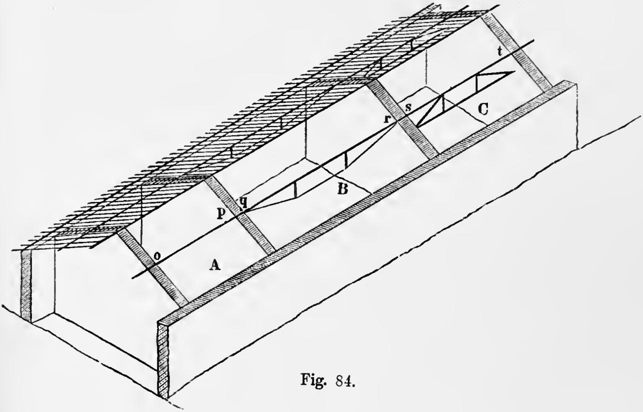


Fig. 84.

It will, however, be a question of economy whether it is more or less expensive to use trussed purlins than to introduce principals between the walls, so as to reduce the bearing of the purlins to such an extent that they may be formed with beams of ordinary scantling.

Fig. 84 shows a portion of a building of the description referred to above. The first space A, being of moderate length, is spanned by a purlin consisting of an ordinary beam *o p*. The next room B, being much longer, is crossed by a purlin, *q r*, trussed with iron rods as described in Part I., while the roof on the third compartment, C, has a wooden purlin *s t* trussed in ordinary queen-post fashion.

The rafters resting upon the purlins are omitted on the near

side of the roof to avoid confusing the figure. The purlins should rest upon stone templates built into the walls; these are not shown in Fig. 84.

In some cases trussed purlins are used in connection with ordinary trussed principals; these latter being placed at a considerable distance apart.

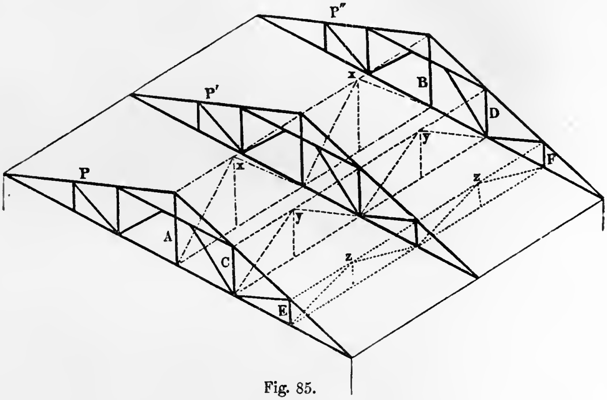


Fig. 85.

For example, in the skeleton diagram Fig. 85, the principals P P P, represented in thick lines, are 20 feet apart, and connected by trussed purlins (each dotted in a different manner), which are shown only on the near side of the roof; those on the farther side being omitted for the sake of clearness.

On these purlins may lie the common rafters, inclining downwards, parallel to the principal rafters, or intermediate principal rafters may be introduced, not forming part of a truss, but resting upon the purlins at *x y z*, and across the principal rafters horizontal common rafters may be placed.

This roof resembles that fixed at Christ's Hospital in 1834, the details of which will be found in Tredgold's Carpentry.

Horizontal Rafters.—Roofs are sometimes constructed with horizontal rafters extending across the principals, at right angles to them, as in Fig. 96. These are in fact purlins, except that they support the roof covering directly, having no rafters upon them.

This is a strong and cheap arrangement, and specially con-

venient when the roof covering is in large pieces, such as sheets of corrugated iron, which can be laid on the rafters without boarding.

When boards are required, they of course extend lengthways down the slope of the roof, and their edges are thus not so liable to be soaked with wet, in case of a leak, as they are when laid parallel to the ridge.

ROOFS OF VARIOUS SHAPES, AND THEIR PARTS.

Different names are given to roofs according to their form.

A **"Lean-to"**[1] roof has only one side or slope, which lies between two walls or other supports one higher than the other. See Fig. 86.

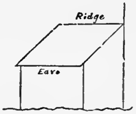


Fig. 86.

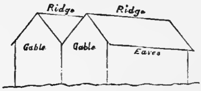


Fig. 87.

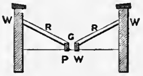


Fig. 88.

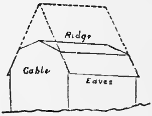


Fig. 89.

A **M Roof** consists of two ordinary triangular roofs side by side (Fig. 87).

A **V Roof** (shown in section, Fig. 88) has two slopes inclining inwards from side walls towards a gutter, which rests upon beams running along the centre of the building, and supported by the party walls PW.

A **Flat-topped Roof** is one in which the apex of the triangle is cut off flat, as in Fig. 96

A **Curb or Mansard Roof** is one in which the apex of a high triangle is cut off and replaced by a flatter summit, as in Fig. 89, and Fig. 98, p. 50.

A **Conical Roof** is shaped like a cone.

An **Ogee Roof** has sides of which the lower portions are

[1] Sc. *To-fall.*

convex outwards and the upper portion concave, thus forming curves resembling that after which they are named. These two last descriptions are seldom required, and will not be further noticed.

The Ridge is the line formed by the meeting of the slopes of a roof at the summit.

The Eaves are the lower edges of the slopes, which rest upon the walls or project over them.

A Gable is formed when the end wall of a building is carried up so as to terminate the roof, as in Fig. 87.

A Hipped Roof[1] is sloped back at the ends as in Fig. 90. These terminating slopes are called the "hipped ends."

Hips[2] are the salient angles formed by the intersection of the sides and ends.

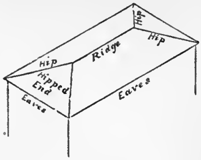


Fig. 90.

Valleys are the intersections similarly formed in re-entering angles (see VR VR, Fig. 91).

A Pavilion Roof is hipped uniformly at both ends, as shown in Fig 90.

Construction of Hipped Roofs.—If a roof terminates in gables, only ordinary principals are required in its construction, but if it is cut into by another roof or is hipped back at the ends special arrangements have to be made for the valleys and hips.

When a simple couple roof is "hipped," deep and narrow "*hip rafters*"[3] HR, Fig. 91, are carried from the end of the ridge to the angles of the end of the building, and short rafters, called "*jack rafters*," *jr*, are cut to fit in between the hip rafters and the wall plates.

The same course is followed in the valley caused by the intersection of two roofs, "*valley rafters*" or *valley pieces* being introduced, as at VR VR in Fig. 91.

In framed roofs the jack rafters fit in between the hip rafters and the wall plates, or between the valley pieces and the ridges.

Fig. 91 is the plan, and Fig. 92 a sectional elevation, of a collar-tie roof covering a building of irregular form.

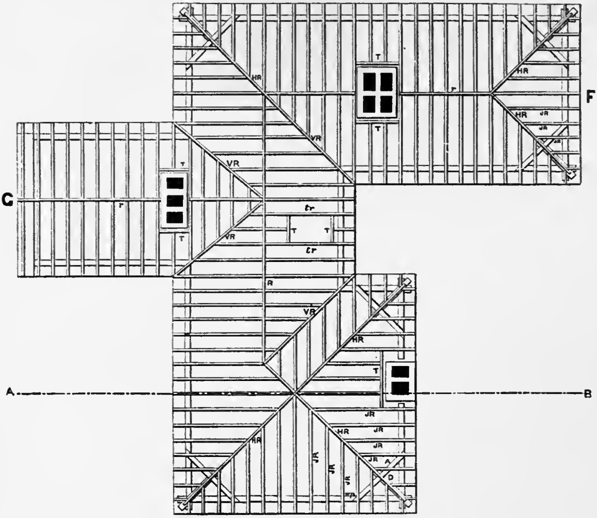
In the former figures, HR HR are the hip rafters, VR VR the valley rafters, DD the dragon pieces in the angles (see p. 48), TT the trimmers carrying the rafters round openings left in the roof for chimneys, skylights, etc.

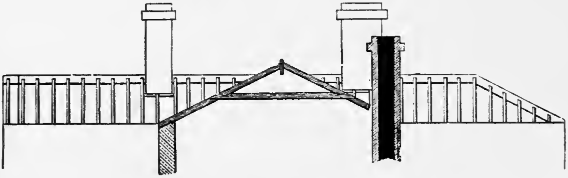
[1] Sc. *Piend roof.* [2] Sc. *Piends.* [3] Sc. *Piend rafters.*

Fig. 92 shows in section the collar-tie roof trimmed to clear the chimney, and in elevation the gable end G, and the end hipped back at F.

Fig. 91. Scale, $\frac{1}{10}$ inch = 1 foot.

Plan.





Sectional Elevation on A B

Fig. 92.

In a larger roof, such for instance as requires king-post trusses with purlins, as in Fig. 93, the length of the purlin, PP, on the hipped end would be too great to be left without support; in such a case a half king-post truss may be introduced at KT.

Similarly in a queen-post roof half principals are placed abutting against the queen posts of the first main truss, and at right angles to it.

In larger roofs flat-topped trusses must be introduced at intervals in the hipped ends to carry the rafters.

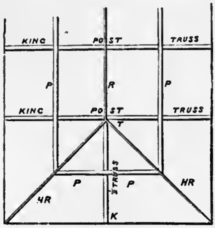


Fig. 93.

Framed Angle.—In a construction such as that described above, the hip rafter being very long and heavy requires to be well supported at its lower end, or it would thrust out the corner of the building; moreover the angle requires to be tied together.

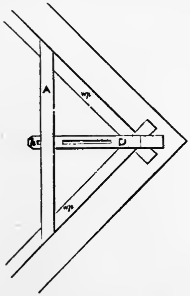


Fig. 94.

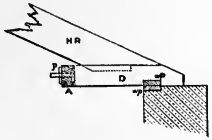


Fig. 95.

These objects are fulfilled by the arrangements shown in Figs. 94, 95. The foot of the hip rafter is tenoned into a mortise in the *dragon beam*[1] D, one end of which is notched into the wall plate *wp*, while the other is furnished with a strong tusk tenon which passes through a hole in the *angle brace* A.

After the hip rafter is fixed it is tightened up by driving a pin into the hole *h*.

Trimming.[2]—Wherever rafters come across any obstacle, such as a chimney, they must be trimmed in the same way as described in Part I. for floor joists. Thus in Fig. 91 the rafters *tr tr*

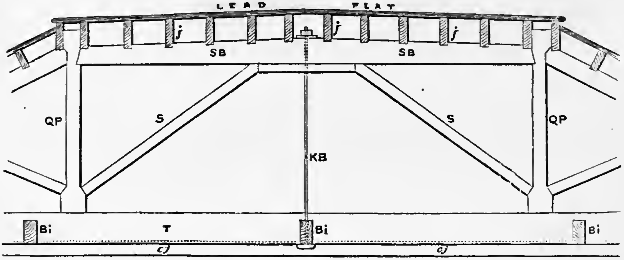
[1] Or dragging-tie. [2] Sc. *Bridling.*

would be made thicker than the others, and a trimmer, T, framed in between them. The rafters are similarly trimmed in order to leave openings for skylights, etc., as shown at T Fig. 186, p. 97.

The roof in Fig. 61, p. 28, is trimmed to clear the chimney; the trimmer is shown in section at T.

The trimmers are often placed vertically, and sometimes supported in the centre by corbels protruding from the chimney.

Flat-topped Roofs.—Fig. 96 shows a method of forming a very nearly flat top to a queen-post roof.



Scale, ¼ inch to 1 foot.
Fig. 96.

The straining beam, SB, is made slightly thicker in the centre, so as to raise the joists, *jjj*, supporting the lead flat, sufficiently to throw off the wet. The rolls for the lead are not shown (see Part I.)

Sometimes rafters at a very flat slope are introduced above an ordinary straining beam to carry the joists.

As a considerable weight comes upon the straining beam, it receives additional support from two struts branching inwards from the feet of the queen posts, and kept asunder by a small straining piece. Fig. 96 shows also binders framed in between the tie beams, as described at p. 42.

Mansard or Curb Roofs were originally introduced in the days of very steep roofs, with a view to diminish their excessive height by cutting of the apex and substituting for it a summit of flatter slope.

This form of roof is condemned by Tredgold as being ungraceful in form, causing loss of room as compared with the original roof of high pitch, and further on account of the difficulty of freeing the gutters from snow. It is, moreover, a dangerous structure on account of its inflammability.

It is, however, much in use at the present time, as it affords an

economical attic story, and is considered by many to be more picturesque than the flatter roofs, while it is certainly much cheaper and less exposed than those of high pitch.

There are several ways of describing the outline of a Mansard roof.[1] Fig. 97 shows Belidor's method,[2] which is the one most usually adopted. It consists in dividing the semicircle, described on the span 0 5, into five equal parts at the points 1, 2, 3, 4, 5; the highest point *r* is then marked, lines joining 0 1 and 4 5 form the sides of the true roof, while 1 *r* and *r* 4 give those of the false roof or summit.

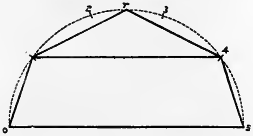


Fig. 97.

Fig. 98 shows an ordinary form of Mansard roof.

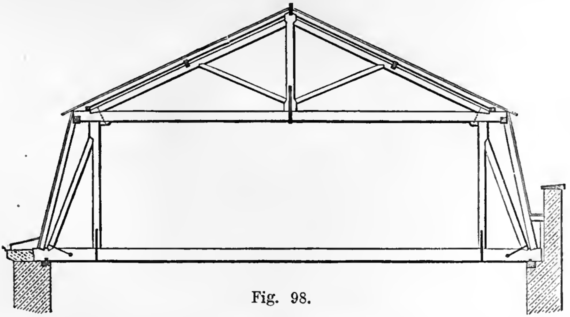


Fig. 98.

Those trusses that come immediately over a partition may be much strengthened if connected with it by prolonging the king post downwards so as to form the centre post of the partition (see Part I.)

Tredgold's Tables of Scantling for Roofs 30 to 60 feet span.—The following tables give the sizes of timbers for roofs of from 30 to 60 feet span.

Those for king-post roofs adapted for spans of from 20 to 30 feet are given in Part I.

[1] Theoretically the beams should be in equilibrium, and support each other without fastenings: to do this they should be arranged in the form they would assume if loosely connected at the ends, and then inverted and allowed to hang in a catenary curve.

[2] From Newlands' *Carpenter's and Joiner's Assistant.*

QUEEN-POST ROOFS, such as in Fig. 77.—TABLES of SCANTLINGS of TIMBER for different Spans, from 30 to 46 feet.

Span.	Tie beam, T.	Queen Post, QP.	Principal Rafters, PR.	Straining Beam, SB.	Struts, S.	Purlins, P.	Common Rafters, CR.
32 ft.	10 by 4½	4½ by 4	5 by 4½	6¾ by 4½	3¾ by 2¼	8 by 4¾	3½ by 2
34 ,,	10 ,, 5	5 ,, 3½	5 ,, 5	6¾ ,, 5	4 ,, 2½	8¼ ,, 5	3¾ ,, 2
36 ,,	10½ ,, 5	5 ,, 4	5 ,, 5¾	7 ,, 5	4¼ ,, 2½	8½ ,, 5	4 ,, 2
38 ,,	10 ,, 6	6 ,, 3¾	6 ,, 6	7¼ ,, 6	4½ ,, 2½	8½ ,, 5	4 ,, 2
40 ,,	11 ,, 6	6 ,, 4	6 ,, 6	8 ,, 6	4½ ,, 2½	8¾ ,, 5	4¼ ,, 2
42 ,,	11½ ,, 6	6 ,, 4½	6¼ ,, 6	8¼ ,, 6	4½ ,, 2¾	8¾ ,, 5¼	4½ ,, 2
44 ,,	12 ,, 6	6 ,, 5	6½ ,, 6	8½ ,, 6	4½ ,, 3	9 ,, 5	4¾ ,, 2
46 ,,	12½ ,, 6	6 ,, 5½	7 ,, 6	9 ,, 6	4¾ ,, 3	9 ,, 5½	5 ,, 2

QUEEN AND PRINCESSES ROOFS, such as in Fig. 80.—TABLE of SCANTLINGS of TIMBER for different Spans, from 46 to 60 feet.

Span.	Tie beam, T.	Queen Post, QP.	Princesses PP.	Principal Rafters, PR.	Straining Beam, SB.	Struts, S.	Purlins, P.	Common Rafters, CR.
48 ft.	11½ by 6	6 by 5¾	6 by 2¼	7½ by 6	8¼ by 6	4½ by 2¾	8½ by 5	4 by 2
50 ,,	12 ,, 6	6 ,, 6¼	6 ,, 2½	8½ ,, 6	8½ ,, 6	4½ ,, 2¾	8¾ ,, 5	4¼ ,, 2
52 ,,	12 ,, 6½	6 ,, 6¾	6 ,, 2¾	9¼ ,, 6	8¾ ,, 6	4¾ ,, 2¾	8¾ ,, 5¼	4¼ ,, 2
54 ,,	12 ,, 7	7 ,, 6¼	7 ,, 2¼	6½ ,, 7	9 ,, 6	4¾ ,, 2¾	8¾ ,, 5¼	4½ ,, 2
56 ,,	12 ,, 8	7 ,, 6¾	7 ,, 2½	7½ ,, 7	9¼ ,, 6	5 ,, 2¾	8¾ ,, 5¼	4½ ,, 2
58 ,,	12 ,, 8½	7 ,, 7¼	7 ,, 2¾	8¼ ,, 7	9½ ,, 7	5 ,, 2¾	9 ,, 5¼	4¾ ,, 2
60 ,,	12 ,, 9	7½ ,, 7	7 ,, 3	9 ,, 7	10 ,, 7	5 ,, 3	9 ,, 5½	4¾ ,, 2

QUEEN AND PRINCESSES ROOFS, with trussed apex, such as in Fig. 81.—TABLE of SCANTLINGS of TIMBER for different Spans, from 60 to 90 feet.

Span.	Tie beam, T.	Queen Post, QP.	Princesses, PP.	Principal Rafters, PR.	Straining Beam, SB.	King Post, KP.	Struts, S.	Purlins, P.	Common Rafters, CR.
65 ft.	15 by 10½	8 by 7	5 by 3	8 by 7½	10½ by 8	5 by 3	5 by 3½	8¼ by 5	4 by 2
70 ,,	15 ,, 11¾	9 ,, 6½	5 ,, 3½	9 ,, 7	10½ ,, 9	5 ,, 3½	5 ,, 4	8½ ,, 5	4¼ ,, 2
75 ,,	15 ,, 13¾	9 ,, 7½	5 ,, 4	9 ,, 8	11¼ ,, 9	5 ,, 4	5 ,, 4½	8¾ ,, 5	4½ ,, 2
80 ,,	16 ,, 13	9 ,, 9	6 ,, 4	10½ ,, 9	12 ,, 9	6 ,, 4	6 ,, 3½	8¾ ,, 5¼	4½ ,, 2
85 ,,	16 ,, 13½	9½ ,, 9	6 ,, 4½	12 ,, 9	12¾ ,, 9	6 ,, 4½	6 ,, 4	9 ,, 5¼	4¾ ,, 2
90 ,,	16 ,, 14	10 ,, 9¾	6 ,, 4½	13½ ,, 10	13 ,, 10	6 ,, 4½	6 ,, 4	9 ,, 5½	5 ,, 2

N.B.—In these Tables the pitch of the roof is supposed to be about 27°; the trusses 10 feet apart. The covering slates and the timber to be good Memel or Riga fir. Inferior timber will require to be of larger dimensions. The scantlings for the tie beams may be considerably reduced when they do not carry ceiling joists. See Seddon's Tables, p. 52.

SCANTLINGS FOR QUEEN-POST ROOFS.

The roofs are supposed to be of Baltic fir covered with Countess slates laid on inch boards; the maximum horizontal wind force is taken at 45lbs. per foot super acting only on one side of the roof at a time, equivalent to a normal wind pressure of 30lbs. per square foot for a pitch of 30°, and 40lbs. per square foot for a pitch of 45°.

The common rafters to be 1 ft. from centre to centre, but in sheltered positions they may be placed 1 ft. apart in the clear.

ROOFS WITHOUT CEILINGS.—Pitch up to 30°.

Nature of Roof.	Span in feet.	‡ Tie beam. *Depth includes 3″ for joints.*	Principal Rafters.	Queen Posts.	Struts.	Straining beam.	§ Purlins. 10 *ft. bearing.*	Common Rafters.
Queen Post. *Trusses* 10′ *centre to centre.*	32	$4\frac{1}{2}'' \times 4\frac{1}{2}''$	$4\frac{1}{2}'' \times 4\frac{3}{4}''$	$4\frac{1}{2}'' \times 2\frac{3}{4}''$	$4\frac{1}{2}'' \times 2\frac{1}{2}''$	$4\frac{1}{2}'' \times 5\frac{1}{2}''$	$5'' \times 7\frac{1}{2}''$	$2'' \times 3\frac{1}{2}''$
	34	$4\frac{1}{2}'' \times 4\frac{3}{4}''$	$4\frac{1}{2}'' \times 5''$	$4\frac{1}{2}'' \times 2\frac{3}{4}''$	$4\frac{1}{2}'' \times 2\frac{3}{4}''$	$4\frac{1}{2}'' \times 6''$	$5'' \times 7\frac{3}{4}''$	$2'' \times 3\frac{3}{4}''$
	36	$4\frac{3}{4}'' \times 4\frac{3}{4}''$	$4\frac{3}{4}'' \times 5''$	$4\frac{3}{4}'' \times 2\frac{3}{4}''$	$4\frac{3}{4}'' \times 3''$	$4\frac{3}{4}'' \times 6\frac{1}{4}''$	$5'' \times 8''$	$2'' \times 4''$
	38	$4\frac{3}{4}'' \times 4\frac{3}{4}''$	$4\frac{3}{4}'' \times 5\frac{1}{4}''$	$4\frac{3}{4}'' \times 2\frac{3}{4}''$	$4\frac{3}{4}'' \times 3\frac{1}{4}''$	$4\frac{3}{4}'' \times 6\frac{3}{4}''$	$5'' \times 8''$	$2'' \times 4''$
	40	$4\frac{3}{4}'' \times 5''$	$4\frac{3}{4}'' \times 5\frac{1}{2}''$	$4\frac{3}{4}'' \times 2\frac{3}{4}''$	$4\frac{3}{4}'' \times 3\frac{1}{4}''$	$4\frac{3}{4}'' \times 7\frac{1}{4}''$	$5'' \times 8\frac{1}{4}''$	$2'' \times 4\frac{1}{4}''$
	42	$5'' \times 5''$	$5'' \times 5\frac{1}{2}''$	$5'' \times 2\frac{3}{4}''$	$5'' \times 3\frac{1}{4}''$	$5'' \times 7\frac{1}{2}''$	$5'' \times 8\frac{1}{2}''$	$2'' \times 4\frac{1}{2}''$
	44	$5'' \times 5\frac{1}{4}''$	$5'' \times 5\frac{3}{4}''$	$5'' \times 2\frac{3}{4}''$	$5'' \times 3\frac{1}{2}''$	$5'' \times 8''$	$5'' \times 8\frac{1}{2}''$	$2'' \times 4\frac{3}{4}''$
	46	$5\frac{1}{4}'' \times 5\frac{1}{4}''$	$5\frac{1}{4}'' \times 5\frac{3}{4}''$	$5\frac{1}{4}'' \times 2\frac{3}{4}''$	$5\frac{1}{4}'' \times 3\frac{1}{2}''$	$5\frac{1}{4}'' \times 8\frac{1}{4}''$	$5'' \times 8\frac{1}{4}''$	$2'' \times 5''$

ROOFS WITH CEILINGS.—Pitch up to 30°.

Nature of Roof.	Span in feet.	‡ Tie beam.	Principal Rafters.	Queen Posts.	Struts.	Straining beam.	§ Purlins. 10 *ft. bearing.*	Common Rafters.
Queen Post. *Trusses* 10′ *centre to centre.*	32	$4\frac{3}{4}'' \times 7\frac{1}{4}''$	$4\frac{3}{4}'' \times 5\frac{1}{2}''$	$4\frac{3}{4}'' \times 3''$	$4\frac{3}{4}'' \times 2\frac{1}{2}''$	$4\frac{3}{4}'' \times 6\frac{3}{4}''$	$5'' \times 7\frac{3}{4}''$	$2'' \times 3\frac{1}{2}''$
	34	$4\frac{3}{4}'' \times 7\frac{3}{4}'$	$4\frac{3}{4}'' \times 5\frac{3}{4}''$	$4\frac{3}{4}'' \times 3''$	$4\frac{3}{4}'' \times 2\frac{3}{4}''$	$4\frac{3}{4}'' \times 7\frac{1}{2}''$	$5'' \times 7\frac{3}{4}''$	$2'' \times 3\frac{3}{4}''$
	36	$4\frac{3}{4}'' \times 8\frac{1}{4}''$	$4\frac{3}{4}'' \times 6\frac{1}{4}''$	$4\frac{3}{4}'' \times 3''$	$4\frac{3}{4}'' \times 3''$	$4\frac{3}{4}'' \times 8\frac{1}{4}''$	$5'' \times 8''$	$2'' \times 4''$
	38	$5'' \times 8\frac{1}{2}''$	$5'' \times 6''$	$5'' \times 3''$	$5'' \times 3''$	$5'' \times 8\frac{1}{4}''$	$5'' \times 8''$	$2'' \times 4''$
	40	$5'' \times 9''$	$5'' \times 6\frac{1}{2}''$	$5'' \times 3\frac{1}{2}''$	$5'' \times 3\frac{1}{4}''$	$5'' \times 9''$	$5'' \times 8\frac{1}{4}''$	$2'' \times 4\frac{1}{4}''$
	42	$5\frac{1}{2}'' \times 9''$	$5\frac{1}{2}'' \times 6\frac{1}{4}''$	$5\frac{1}{2}'' \times 3\frac{1}{2}''$	$5\frac{1}{2}'' \times 3''$	$5\frac{1}{2}'' \times 9''$	$5'' \times 8\frac{1}{2}''$	$2'' \times 4\frac{1}{2}''$
	44	$5\frac{1}{2}'' \times 9\frac{1}{2}''$	$5\frac{1}{2}'' \times 6\frac{3}{4}''$	$5\frac{1}{2}'' \times 3\frac{1}{2}''$	$5\frac{1}{2}'' \times 3\frac{1}{4}''$	$5\frac{1}{2}'' \times 9\frac{1}{2}''$	$5'' \times 8\frac{1}{2}''$	$2'' \times 4\frac{3}{4}''$
	46	$5\frac{1}{2}'' \times 10''$	$5\frac{1}{2}'' \times 7\frac{1}{4}''$	$5\frac{1}{2}'' \times 4''$	$5\frac{1}{2}'' \times 3\frac{1}{2}''$	$5\frac{1}{2}'' \times 10''$	$5'' \times 8\frac{3}{4}''$	$2'' \times 5''$

For roofs of 45° *pitch.*—Add 1″ to the depth of common rafters, purlins, and struts, and $\frac{1}{2}''$ to the depth of the principal rafters, as given in Tables I. and II.

§ If *the purlins*, instead of being placed immediately over the joints, are placed at intervals along the principal rafter increase the depth of the latter, given in the tables, as follows:

$$\text{Queen-Post roof}\begin{cases}\textit{without} \text{ ceiling } 1\frac{1}{4}'' \\ \textit{with} \quad ,, \quad \frac{1}{2}''\end{cases}$$

The purlins if placed 2 feet apart and with 10 feet bearing may be made 3″ × 6″.

The scantlings of the principal rafters, struts, and straining beam can be *slightly* modified by means of the following rough rule: "For every $\frac{1}{4}''$ deducted from the *lesser* dimension of the scantling, add $\frac{1}{2}''$ to the other dimension, and *vice versâ.*" For the tie-beam, purlins and common rafters, so long as the depth is about double the breadth, $\frac{1}{4}''$ deducted from the breadth requires $\frac{1}{4}''$ to be added to the depth.

‡ *The joint of the tie-beam with the principal rafter* should be placed immediately over the supporting wall. If this cannot be conveniently done, the depth of the tie-beam should be increased one or two inches.

These tables, compiled by Major H. C. SEDDON, R.E., from calculations by Lieut. H. R. SANKEY, R.E., have been followed in the construction of a large number of W.D. buildings

TREDGOLD'S RULES FOR SCANTLING OF ROOF TIMBERS.

The following rules laid down by Tredgold will be useful to those who are unable to find the direction and amount of the stresses on various parts of a roof; and thus by a more accurate method to arrive at the sizes necessary for the different members.

The student should observe that though these look like complicated formulæ, they are very simple, being merely letters substituted for words, as in Hurst's Pocket-book, and they require nothing but ordinary arithmetic for their application.

B = Breadth of piece in inches. D = Depth of piece in inches. A = Area of section of piece in inches = B × D. L = Length of piece in feet. S = Span of roof in feet.

Tie Beam.—u = Length of longest unsupported part in feet.

When the tie beam has to support a ceiling only.

$$D = \frac{u}{\sqrt[3]{B}} \times 1{\cdot}47 \text{ for fir, or } \times 1{\cdot}52 \text{ for oak.}$$

When there are rooms above, the tie beam must be calculated as a girder (see p. 102, Part I.)

Ceiling Joists 12 inches from centre to centre.

$$D = \sqrt[3]{\frac{L}{\sqrt{B}}} \times 0{\cdot}64 \text{ for fir, or } \times 0{\cdot}67 \text{ for oak.}$$

King Post.—$A = L \times S \times 0{\cdot}12$ for fir, or $\times\ 0{\cdot}13$ for oak.

King Bolt.—Diameter in inches = $\sqrt{S} \times 0{\cdot}2$.

Queen Post.—t = length in feet of part of tie-beam suspended by the queen post.

$A = L \times t \times 0{\cdot}27$ for fir, or $\times\ 0{\cdot}32$ for oak.

Queen Bolt.—Diameter in inches = $\sqrt{t} \times 0{\cdot}29$.

Struts and Braces.—r = length of part of principal rafter supported by the strut, in feet.

$$D = \sqrt{L \times \sqrt{r}} \times 0{\cdot}8 \text{ for fir.}$$

$$B = \tfrac{6}{10}\,D.$$

Principal Rafters.—Supported by struts over which the purlins rest.

In King-post roof.—$D = \frac{L^2\,S}{B^3} \times {\cdot}096$ for fir.

In Queen-post roof.—$D = \frac{L^2\,S}{B^3} \times 0{\cdot}155$ for fir.

The thickness is generally the same as that of the tie beam and king or queen posts.

Purlins.—C = distance in feet that the purlins are apart.

$$D = \sqrt[4]{L^3 \times C} \times 1{\cdot}0 \text{ for fir, or } 1{\cdot}04 \text{ for oak.}$$

$$B = \tfrac{6}{10}\,D$$

Common Rafters.—$D = \frac{L}{\sqrt[3]{B}} \times 0{\cdot}72$ for fir, or $0{\cdot}74$ for oak.

Straining Beam.—In the best form for strength the depth is to breadth as 10 to 7.

$$D = \sqrt{L \times \sqrt{S}} \times 0{\cdot}9 \text{ for fir.}$$
$$B = \tfrac{7}{10} D.$$

BEST FORMS OF ROOF FOR DIFFERENT SPANS.

The best form of roof truss or principal to be used for a given span is determined by the following considerations:—

1. The parts of the truss between the points of support should not be so long as to have any tendency to bend under the thrust; therefore the length of the parts under compression should not exceed twenty times their smallest dimension. This will be explained in Part IV.

2. The distance apart of the purlins should not be so great as to necessitate the use of either purlins or rafters too large for convenience or economy.

3. The tie beam should be supported at such small intervals that it need not be too large for economy or convenience.

It has been found by experience that these objects can be attained by limiting the distance between the points of support on the principal rafter to 8 feet.

In determining the form of truss for any given span, it is therefore necessary first to decide the pitch, then roughly to draw the principal rafters in position, ascertain their length, divide them into portions 8 feet long, and place a strut under each point of division.

By this it will be seen that a king-post truss is adapted for roofs with principal rafters 16 feet long, *i.e.* those having a span of 30 feet. A queen-post truss would be adapted to a roof with principal rafters 24 feet long, that is of about 45 feet span.

For greater spans with longer principal rafters, roofs such as that in Figs. 80 to 83 must be used.

Chapter III.

ROOF COVERINGS.

General Remarks.—Roofs are covered with different materials, according to the locality, the climate, and the nature and importance of the building

As a rule, the smaller the pieces in which the covering is put on, the heavier will it be, and the more difficult to keep watertight, as it will contain a greater number of openings or of joints.

Substances which conduct heat very slowly, such as slate, make better coverings than the metals; the former preserve an equable temperature, while the latter conduct the heat in summer, and the cold in winter, to the interior of the building.

Pitch of Roofs.—The pitch, or inclination of the sides of a roof, is determined chiefly by the nature of the covering.

Thus thatch, which would easily allow wet to penetrate it, must be laid at a steep angle, so as to throw the water off at once; whilst, on the other hand, hard and impervious slates may be laid at a much smaller angle, and sheets of metal may be nearly flat.

The pitch is, moreover, varied greatly to suit different styles of architecture, and also according to climate. Some writers have gone so far as to prescribe an exact pitch for every variation in latitude.

The following remarks by the late Professor Robison are of a more practical character:—

"A high-pitched roof will undoubtedly shoot off the rains and snows better than one of lower pitch; the wind will not so easily blow the dripping rain in between the slates, nor will it have so much power to strip them off;" and further—"A high-pitched roof will exert a smaller strain upon the walls, both because its strain is less horizontal, and because it will admit of lighter covering; but it is more expensive, because there is more of it,—it requires a greater size of timbers to make it equally strong, and it exposes a greater surface to the wind."

The pitch of a roof is expressed either by the angle which its sides make with the horizon, or by the proportion which its height in the centre bears to the span.

Thus the roof shown in Fig. 77, p. 39, may be said to have a pitch of $26\frac{1}{2}$ degrees or $\frac{1}{4}$.

The subjoined table, taken chiefly from Tredgold, gives the inclination for roofs covered in different ways. The weights of various coverings are also given, but these will vary considerably according to the quality and thickness of the material used.

TABLE.

Kind of Covering.	Inclination of sides of Roof to Horizon.	Height of Roof in parts of Span.	Weight on a square (*i.e.* 100 square feet) of roofing in lbs.
Asphalted Felt . .	3° 50′	$\frac{1}{30}$	30 to 40
Copper	3° 50′	$\frac{1}{30}$	80 to 120
Corrugated Iron, 16 BWG[1]	4° 0′	$\frac{1}{29}$	350
Sheet Iron, 16 BWG .	18° to 20°	$\frac{1}{6}$	250
Lead	3° 50′	$\frac{1}{30}$	550 to 850
Slates (large) . . .	22° 0′	$\frac{1}{5}$	900 to 1100
,, (ordinary) . .	26° 30′	$\frac{1}{4}$	550 to 800
,, (small) . .	30° 0′	$\frac{1}{3}$	450 to 650
Slabs of Stone . .	39° 0′	$\frac{2}{7}$	2380
Thatch (Straw) . .	45° 0′	$\frac{1}{2}$	650
Tiles (Plain)[2] . .	$52\frac{1}{2}$°	$\frac{4}{3}$	1800
,, (Pan) . . .	24° 0′	$\frac{2}{9}$	1200
,, (Taylor's Patent) .	30° 0′	$\frac{1}{3}$	830
Zinc ($\frac{1}{32}$ in. thick) . .	4° 0′	$\frac{1}{25}$	150
Boarding ($\frac{3}{4}$ thick) . .	26° 30′	$\frac{1}{4}$	250
,, 1 ,, . .	26° 30′	$\frac{1}{4}$	350

N.B.—The additional pressures to be taken into account in practice are the following:—

Pressure of wind . . . . 2500 to 5000 lbs. per square of 100 feet.
do. of snow, in this country 500 lbs. per square.

Slating.—The particulars connected with the different methods of laying slates, also slate ridges and hips, have been entered upon in Part I., chap. ix., and need not here be repeated.

Tiles of burnt clay are made in several different forms, a few of the more important of which will be described.

They are heavy and rather apt to absorb moisture, and to communicate it to the laths and rafters of the roof, thus rendering the latter liable to decay.

[1] BWG stands for Birmingham wire-gauge—a measure of thickness (see Part III.)
[2] Plain tiles are used on roofs of any pitch from 30° to 60°.

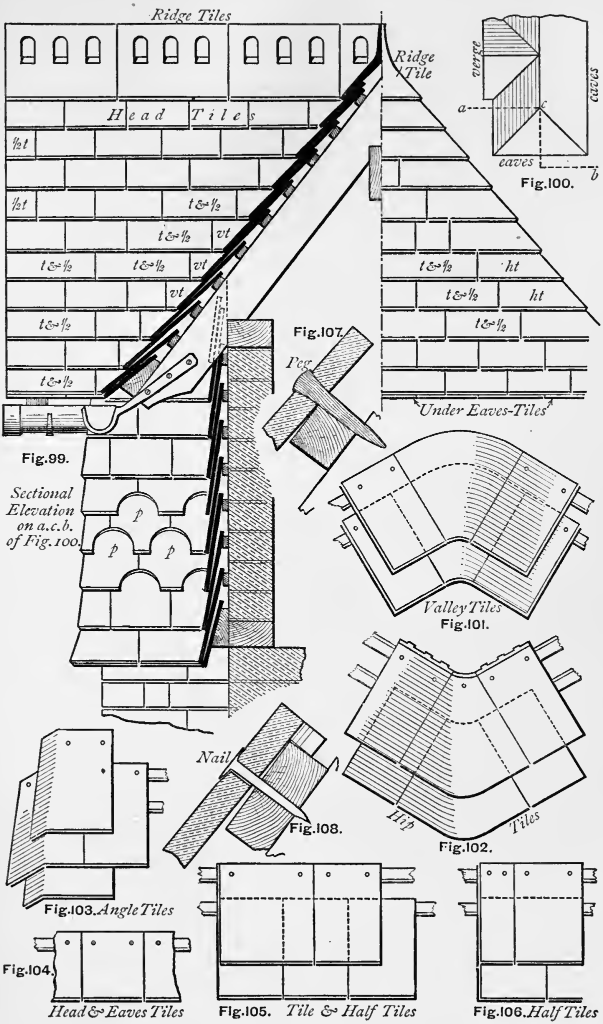

Ridge Tiles
Ridge Tile
Head Tiles
½t
t & ½
vt
ht
Under Eaves-Tiles
verge
eaves
a
b
c
Fig.100.
Fig.107.
Peg
Fig.99.
Sectional Elevation on a.c.b. of Fig.100.
p
Valley Tiles
Fig.101.
Nail
Fig.108.
Hip Tiles
Fig.102.
Fig.103. Angle Tiles
Fig.104.
Head & Eaves Tiles
Fig.105. Tile & Half Tiles
Fig.106. Half Tiles

PLATE II.

PLAIN TILES are slabs of burnt clay, either rectangular or in various patterns, as at *p, p,* Fig. 99, Pl. II., generally about $10\frac{1}{2}$ inches long, $6\frac{1}{2}$ inches wide, and about $\frac{1}{2}$ inch thick. They are slightly curved in their length to make them lie close.

They are laid on battens $1\frac{1}{2}$ inch $\times$ $\frac{1}{2}$ inch, or on laths of oak or fir, being hung from them by wooden pins driven through holes near the upper edge of the tiles. Sometimes the tiles are hung by projecting nibs, of which there are generally two or three upon their upper edges. Sometimes only every third or even only every tenth course is nailed.

The arrangement of the tiles is similar to that of slates—the tail of each rests upon the tile below for a length of about 6 inches, the gauge being 4 inches (often $3\frac{1}{2}$ inches) and the lap over the head of the tile next but one below about 3 inches.

WEATHER TILING.[1]—Plain tiles are often used vertically to protect walling. Battens are nailed upon the wall, and the tiles hung upon them in somewhat the same manner as for roofs,—each tile being bedded in mortar so as to make the covering warm and weather-tight.

Plate II. shows in Figs. 99, 100, part of a plain tiled roof and of a wall with hanging tiles. Figs. 101-106 show various forms of tiles which are necessary to make good work, as shown in Fig. 99.

Fig. 107 shows the method of securing a tile by a pin which should be preferably of oak or otherwise of heart of Memel cut with a knife out of any dry stuff. Fig. 108 shows a tile secured by a nail which should be of copper or of malleable iron.

Ridges may be as shown in Fig. 99. Sometimes the ridge tiles have longitudinal grooves along their upper edges, into which detached ornamental "fleurs" are fitted. Sometimes they have ventilating openings in them.

Torching and Pointing.—The tiles after being laid should be *torched or tiered,* that is pointed from the inside with hair mortar. The *Verges* (see Fig. 100) should be pointed in cement, and the ridges, finials, etc., set in cement. In very exposed places each tile may be bedded in hydraulic mortar or cement upon those below it.

PAN TILES form a covering not so warm as one of plain tiles, and liable to injury from gusts of wind.

The tiles are about 14 inches long by 9 inches straight across the width. Each is hung on to the laths or battens, *b b,* by a nib which projects from the upper edge of the back of the tile,—

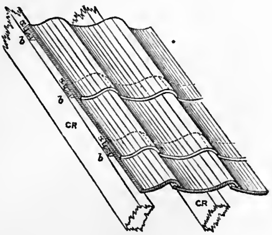


Fig. 109.

[1] Or *Hanging Tiling.*

shown in section at x x x. It should be remarked that this projection is not continuous throughout the width of the tile, but is only about one inch wide.

The tiles have a lap of 3 inches to 4 inches, and the joints on the under sides are pointed with hair mortar.

Pan tiles are well adapted for roofing over workshops where large furnaces are used, as they withstand the heat, and the interstices between them afford plenty of ventilation.

Half round or concave tiles set in mortar, and nailed to the woodwork, are used for the ridges, hips, and valleys. For common work sometimes the tiles themselves are used—the smaller curved portion being cut off,—but special tiles are generally made for the purpose.

In exposed situations, and where much ventilation is not required, the tiles are bedded on each other in mortar, and the space between the ridge tiles and those in the ridge courses at the top of the slopes are filled in with pieces of flat tiles bedded in mortar.

Glass Tiles of this form are made, and may be introduced among the others where light is required. *Double Roll Tiles* are similar to the above, but have a double wave in their width. *Corrugated Tiles* are similar in general form to pan tiles, but they are bent into several narrow curved or sometimes angular corrugations, instead of only two broad ones.

Italian Tiles are shown in section and elevation in Figs. 110, 111, from which the construction of the tiles is obvious.

These tiles present a handsome appearance, which leads to their

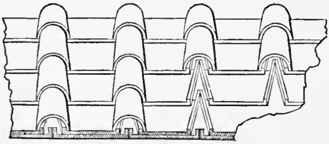


Fig. 110. *Elevation.*

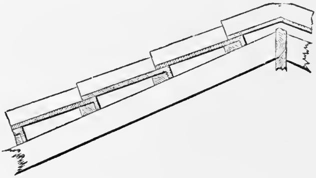


Fig. 111. *Section.*

use in some cases; but they are not well adapted to the British climate, as they cause the snow to lodge, and, when it thaws, the water frequently gets through the roof.

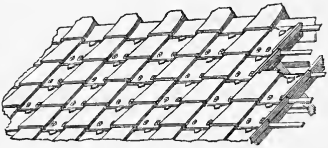


Fig. 112.

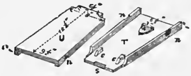


Fig. 113.

Taylor's Patent Tiling is somewhat similar in principle to the Italian tiling just described.

In this case, however, the upper or *capping tiles* are exactly like the lower or *channel tiles*, so that every tile can be used in either position.

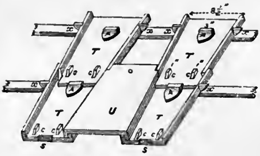


Fig. 114.

Fig. 112 shows the general appearance of this kind of tiling, which is very picturesque.

Fig. 113 gives an upper and lower view of the tiles.

Fig. 114 shows a few channel tiles, T T, with one capping tile, U, in position.

The tiles are hung on battens $2\frac{1}{4}$ inches wide and 1 inch thick, laid to about a 10-inch gauge. The channel tiles are first laid in rows along the slope of the roof from eaves to ridge; the narrow end of each tile is pushed into the wide end of the one below until the splay, *s*, fits firmly into the undercut in the shield, A, of the lower tile.

There are notches in the sides of the tiles, as shown at *n n* Fig. 113; each channel tile is secured by wedge-shaped nails[1] driven in alongside, so as to hold the tile down by these notches as at *x x*.

After the channel tiles are all fixed, the capping tiles are put on. These tiles are turned over, and so placed as to cover the intervals between the channel tiles. They are pushed downwards until the little blocks or cogs, *c c*, rest upon the nail-heads, *x x*, which secure the channel tiles below.

The under side of the corners of the joints between the tiles is pointed with cement mortar.

Foster's Lock Wing Roofing Tiles are illustrated in Fig. 115,[2] which explains itself. It is claimed for these tiles that they are cheaper than the

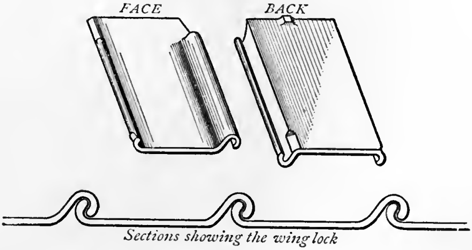


Fig. 115.

commonest tiles made, can be hung quickly and without skilled labour, require no pointing, and cannot be blown off the roof, as the stronger the pressure is underneath, the tighter the lock.

---

[1] Or side keys. [2] From the Patentee's Circulars.

Poole's Patent Bonding Roll Roofing Tiles are shewn in Fig. 116 [1], which requires no description.

Fig. 116.

Thatch is made of wheaten straw [2] laid on laths nailed (8 inches apart) to rafters, frequently of a very rough kind. This covering keeps a building warm in winter and cool in summer, but it is very subject to destruction by fire or decay, and generally forms a refuge to insects and vermin.

The pitch should be 45°. If it is less the rain will not run off freely; if more, the straw slips down.

The thatch is sewn down on the lathing in small bundles, until it attains a thickness of from 12 to 16 inches over the roof generally, but it is sometimes thinned down to nothing, just at the eaves.

About $3\frac{1}{2}$ cwt. of wheat straw is required per square. It will last in England from fifteen to twenty years,—oat straw about eight years.

Wrought Iron plain sheets are sometimes used, the longitudinal joint down the slope being formed by bending the two edges of adjacent plates over a roll of wood.

Corrugated Iron plates are much used.[3] They are made in sheets varying in size from 6 feet × 2 feet to 8 feet × 3 feet, and in thickness from $\frac{1}{45}$ to $\frac{1}{16}$ inch, that is, from No. 24 to No. 16 Birmingham wire gauge. The sheets of medium thickness (for example, of No. 20 gauge with 5-inch flutes) require to be supported only at intervals of from 6 to 8 feet, and the roof may thus be cheapened by omitting the intervening purlins. Ordinary corrugated iron is so laid that the flutes run down parallel to the slope of the roof. The sheets overlap at the sides, and should be screwed at the top and bottom edges to the roof timbers. The screws should be on the ridges of the corrugations, so that all wet may at once be thrown off them.

Corrugated iron is sometimes laid with the flutes horizontal, so that the sheets span the interval between the principals, and all

[1] From the Patentee's Circulars.

[2] Reeds make the best thatched roofs, but the use of reeds for roofing has nearly died out.

[3] See Part iii., p. 288.

rafters and purlins can be dispensed with. In such a case the flutes should be of a peculiar angular shape,[1] so as to throw off the water.

Corrugated iron is often galvanised, but if the coating be once pierced it is soon destroyed by the voltaic action between the two metals; it is, therefore, better merely to paint the surface.

It is sometimes protected from atmospheric influences by an external covering of asphalted felt, which is made to adhere to it by means of a composition.

Corrugated iron is frequently used not merely as a covering, but to form the roof itself, the sheets being riveted together and bent into an arched form.

Sheet Lead is used for covering flat roofs, and also for many portions of ordinary roofs, such as the gutters and flashings; the different methods of laying it are described in Part I.

Lead is not adapted as a covering for pitched roofs, owing to its expansion and contraction, by virtue of which it will crawl down a roof. During a warm day it expands, the expansion being assisted downwards by the action of gravity; in the cool night it contracts, the contraction being diminished by the force of gravity acting downwards: the consequence is it contracts each night less than it expanded during the day, and in time gains a considerable distance.[2]

Copper is sometimes used in sheets weighing about 16 ounces per foot superficial. They should be laid on boards in the same manner as those of lead. The coating of oxide formed by the action of the air preserves the surface to a certain extent, but the first cost of this metal is so great as to prevent its being much used.

Zinc is laid as a roof covering in several different ways.

Its lightness, as compared with slates, tiles, or lead, enables it to be laid on roof-timbers of much smaller scantlings than those required for the coverings just mentioned.

The method of laying zinc in this country has been greatly improved through the exertions of the Vielle Montagne Zinc Company, from whose beautifully illustrated pamphlet[3] on the subject the figures and most of the information here given have been extracted.

There are several methods of laying zinc on roofs; in all of them the object should be to avoid soldered and rigid connection, and to arrange the joints so that they may be water-tight, but may still allow free play for contraction and expansion of the metal under changes of temperature.

[1] See Part III. p. 288.

[2] The lead on the moderately-inclined roof of Bristol Cathedral crawled down 18 inches in two years—Tyndall, *Heat as a Mode of Motion*.

[3] Published by their manufacturing agents, Messrs. F. Braby and Company.

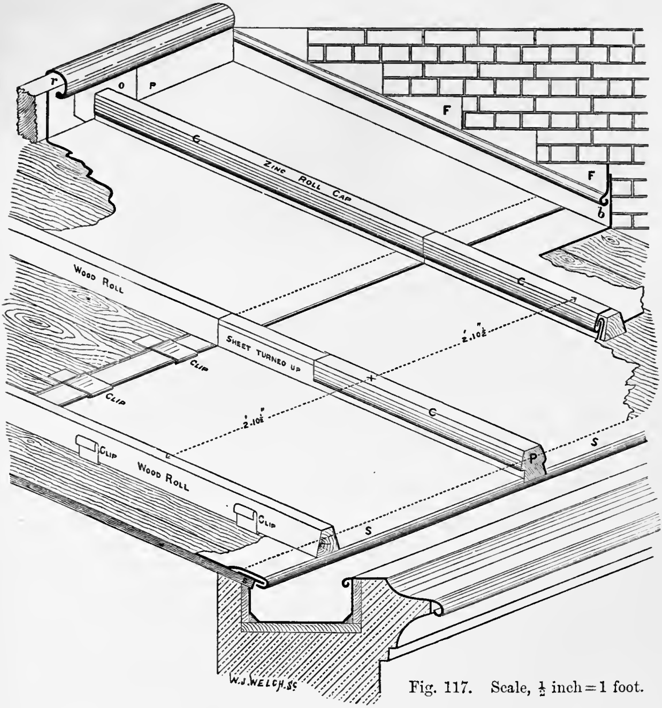


Fig. 117. Scale, ½ inch = 1 foot.

Zinc laid with plain Roll Caps on boarding.—Flat sheets of zinc from 7 to 10 feet long and 3 feet wide, are laid with wooden rolls on boarding very much in the same manner as lead.

Fig. 117 shows a portion of a roof covered in this manner. The sheets run lengthways down the slope of the roof, their side edges being turned up against the rolls, which are placed 2 feet $10\frac{1}{2}$ inches apart from centre to centre.

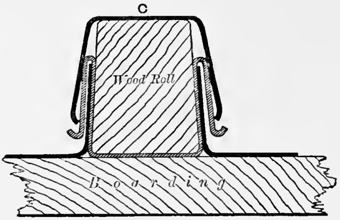


Fig. 118.

A section of one of these rolls, showing the method of securing the zinc, is shown on a larger scale in Fig. 118.

The scored portion of the section shows one of the zinc clips, which are strips about 2 inches wide, fixed about 3 feet apart along the roll. Being doubled over the upturned side edges of the sheets, the clips hold them down, without preventing their expansion and contraction under changes of temperature.

After the sheets are laid and secured by the clips, the rolls are covered by the cap C, also formed of sheet zinc, doubled down as shown. In very exposed situations these clips may be continued so as to turn up again over the sides of the cap C, and be secured at the top.

The cap is secured by "fork connections." These consist of pointed pieces of zinc 2 or 3 inches long by about an inch wide, one end of which is soldered to the inner surface of the cap on each side, the point being free. As the cap slides on to the roll, the points of these forks slip in under the hooked portion of the clip. They thus prevent the clip from flying off, without impeding its expansion and contraction in direction of its length.

Braby's Patent Saddle-piece and Stop-end.—The extreme ends of the roll caps may be covered with a piece soldered on, as shown at O and P; but this plan has been improved upon by merely spreading out the roll cap itself at O, forming what is called a saddle-piece, and dressing it up against the side of the ridge; and at the end, P, by turning the end of the cap over the end of the roll, and doubling the corners of the sides of the cap under the end—thus, in both cases, doing away with soldered joints, and allowing perfect play under expansion and contraction. There are other patented methods of effecting the same object, which cannot here be described.

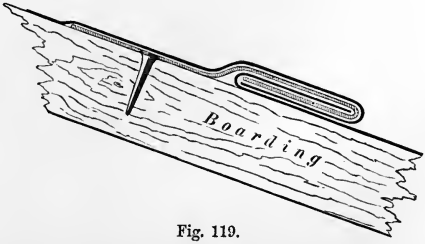


Fig. 119.

WELTED JOINTS.—The sheets having been fastened at the sides by means of the rolls as above described, it next becomes neces-

sary to make a connection between the lower edge of each sheet and the upper edge of the sheet next below it on the slope of the roof (Fig. 117).

This is done by means of the joint shown in section in Fig. 119 and called a *Welt* or *Fold* joint.

In this figure the hatched section is that of a "clip," or strip of zinc about 2 inches wide nailed to the boarding, and doubled in between the edges of the two sheets to be connected, which are shown in section by the black lines, so as to make a secure joint, and yet to give them plenty of play for expansion and contraction.

Welted joints are used only when the roof has a slope of $\frac{1}{7}$ or more; for flatter roofs drips are introduced.

The lower edges of the sheets nearest the eaves are strengthened where they project over the gutter, by being doubled back so as to form a bead; and further, by a strip of stout zinc (S in Fig. 117), nailed along the edge of the boarding over which the bead is formed.

The ridge is covered by a zinc roll cap turned over it, which latter is strengthened on the lower edges by their being bent round to form beads.

Drips.—Zinc may be fixed with rolls on boarding laid upon roofs of any pitch not less than about 1 in 15.

When, however, the slope of the roof is flatter than $\frac{1}{7}$, drips should be formed similar to that shown in Figs. 120, 121, at intervals of from 7 to 8 feet, that is at the end of each sheet.

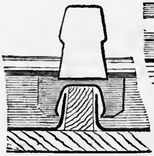


Fig. 120. *End Sectional Elevation.*

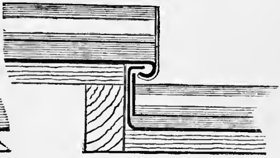


Fig. 121. *Side Sectional Elevation.*

The figures show the end elevation and the section of a drip joint over a roll.

The thick lines show the sections of the sheets, the ends of which, it will be noticed, are bent inwards, so that they may be able to expand and contract without danger of any water getting in behind the joint.

The stopped end of the roll cap on the upper level is bent over with the edge of the sheet.

Drips in flats should be $2\frac{1}{2}$ inches deep, and in gutters $1\frac{1}{2}$ inch deep.

Zinc laid with patent drawn Roll Cap.—Another form of roll patented by the Vielle Montagne Zinc Company is recommended as lasting longer than the simple form just described, and as being peculiarly suitable "for terraces or flats of warehouses where weights are stored, or where there is much walking about;" and, as regards appearance, for Mansard or high-pitched roofs.

The method of laying zinc with these rolls is somewhat similar to that with the ordinary rolls; but the loose zinc roll cap is done away with, the zinc being drawn tight over the roll by machinery.

CORRUGATED ZINC ROOF.—When the zinc is required to be laid without boarding—which is, of course, a great saving—it must be strengthened by corrugations, *i.e.* by curved indentations or flutes formed along the sheet.

The ordinary corrugated zinc consists of flutes about $3\frac{1}{2}$ inches wide, lying close together.

It is laid in a similar way to corrugated iron (p. 61), the purlins being placed about 2 feet 6 inches apart.

Italian Corrugated Zinc Roof.—In this form of zinc the corrugations are spaced more widely, being 1 foot 3 inches apart.

In Fig. 122 one sheet is shown in section by the thick black line, the ends of the adjacent sheets being scored in section.

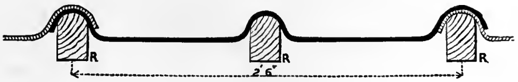


Fig. 122.

The zinc may be laid upon rafters, so spaced and shaped as to fit into the corrugations (Fig. 122), but for the sake of durability it is better to lay it upon boarding.

The sheets are secured to them, either by patent holding down clips shaped so as to allow of the expansion and contraction of the sheets, or by patent sliding studs. Both methods are fully described in Messrs. Braby's pamphlet.

Fig. 122 shows in section a portion of a roof covered with Italian corrugated zinc. The zinc rolls or rafters are 1 foot 3 inches apart, and are supported upon purlins, which in large roofs may be 10 feet apart.

The depth of the rolls when they act as rafters, and are laid

upon purlins about 7 feet apart, is about 3 inches; but when laid upon boarding they are only 2 inches deep.

Thickness of Zinc for roofing.—The gauges[1] recommended by the Vielle Montagne Company are Nos. 14, 15, and 16 zinc gauge (see Part III.) for the roof covering.

"No. 14 to be used only where it is necessary to exercise the greatest possible saving in the first cost."

No. 15 or 16 for gutters.

Nos. 14 and 15 for flats.

Nos. 13 and 14 are frequently used for roofing, where economy is an object.

It must be noted that these are the numbers of the Vielle Montagne Company's *zinc* gauge, not of the ordinary Birmingham wire gauge.

Zinc Flashings are very similar to those of lead described in Part I. An illustration of one is shown at F in Fig. 117.

The edge of the sheet is generally turned up about 6 inches against the wall, and the apron over it is finished and stiffened by being bent round to form a bead *b* as shown.

The ridge roll is covered with zinc in nearly the same manner as with lead, except that the zinc is not worked so much into the angles under the roll. It is secured by forks, similar to those described in page 64.

ZINC GUTTERS.—*Valley Gutters* are formed in somewhat the same manner as those of lead.

For roofs laid with wood rolls the wooden trough is lined with sheet zinc,—the sides of which are turned up, and the upper edges bent inwards under the bead formed by the lower edge of the sheet at the eaves.

Where Italian corrugated zinc is used the sides of the zinc lining to the gutters are turned up, and the edges bent over the thickness of the wood sides of the trough.

The minimum fall for such gutters should be $\frac{1}{40}$.

Zinc Tiles, generally of diamond or shield shape, are sometimes used for roof coverings, each being hung from a hook fixed upon battens or boarding, and passing through a hole near the top of the tile.

Zinc Eaves Gutters[2] are made of various forms, very similar to those of cast-iron, and are fixed in the same positions.

They soon perish, and are hardly strong enough to bear the weight of snow or even the pressure of a ladder.

Zinc gutters, not being so strong as those of iron, require stays about 1 foot 6 inches apart. These are simply hollow cylinders of zinc—placed across the gutter—through which is passed the screw fixing the gutter to the

[1] For the thickness of the various gauges see p. 346, Part III.

[2] Sc. *Rhones.*

wood-work. The stay keeps the upper part of the gutter from bending inwards as the screw is driven home.

The various gauges for zinc and other metals are given in Part III., whence the following remarks are taken.

Zinc should not be allowed to be in contact with iron, copper, or lead. In either case voltaic action is set up, which soon destroys the zinc. This occurs especially and more rapidly when moisture is present.

Zinc should also be kept clear of lime or calcareous water, and of any wood, such as oak, which contains acid. Zinc laid on flats or roofs where cats can gain access is very soon corroded.

An objection to zinc for roofs is that it catches fire at a red heat, and blazes furiously.[1]

Glass is very frequently used as a covering for the whole or parts of roofs, such as those of railway stations, manufactories, etc. etc.

In some cases where a maximum of light is required, clear glass must be used; but, as a rule, patent rolled rough plate will admit sufficient light, and it is always much stronger.

The glass is laid upon sash bars of iron or wood. The former may be of cast-iron, similar in section to wooden sash bars, or of wrought-iron of ⊥ section. The unequal contraction of iron and glass renders it difficult to keep a tight joint between them.[2]

Asphalted Felt.—This material is, as has already been noticed, often used under slates on account of its being waterproof and a non-conductor of heat.

It is, however, also adapted as a roof covering alone, for temporary buildings, being fixed to boarding by copper, zinc, or iron clout nails (the last being dipped in oil). The felt should be stretched tight, the joints between the pieces overlapped, and the whole paid over with hot tar and lime boiled together, and then sanded.

Willesden paper and *wire wove roofing* are also used for temporary roof coverings, and are described at pages 456, 457, Part III.

[1] Bloxam. [2] For patent systems of glazing see p. 204.

Chapter IV.

JOINERY.

MOULDINGS.

MOULDINGS are required merely for ornament. The most ordinary forms are generally parts of a circle in section; and it is recommended that they should not have much projection, the lines of shade being produced rather by deep grooves.

When a moulding is formed on the edge of a piece of timber in the substance of the wood itself, it is said to be "*stuck*," see Fig. 123.

When it is on a separate slip of wood, and attached to the piece it is to ornament, it is said to be "*laid in*" or "*planted*," see Fig. 139.

These terms are the same as those used for beads and explained in Part I.

In ordinary panelled work the mouldings are as a rule in separate slips, bradded or "planted" on to the inner edges of the frames, not on to the panels, as the shrinkage of the latter would draw them away from the frame.

If, however, the moulding is "stuck" on the frame, the groove for the panel should be deeper than the moulding, otherwise, when the framing shrinks, daylight will be seen through the open mitred corners of the moulding.

Figures 123 to 128 are sections of some of the commonest classical mouldings, which are named as follows:—

Fig. 123.

The Torus (Fig. 123) is a semi-cylindrical projection, surmounted by a flat band called a "fillet."

The Double Torus consists of two such semi-cylindrical projections, the upper one being smaller than the other and surmounted by a fillet.

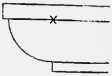


Fig. 124.

The Ovolo (Fig. 124) is a curved convex projection surmounted by a fillet.

The ovolo shown in Fig. 124 is a quarter-circle in section, but it may be a portion of an ellipse or hyperbola.

The Double Ovolo consists of two ovolo mouldings opposite to one another, as in the sash bar Fig. 311, Part I.

The Cavetto (Fig. 125) is the reverse of the Ovolo, being a concave quadrant.

Fig. 125.

The Ogee or Cyma Recta (Fig. 126) consists of two curves tangent to one another, the upper being concave and the lower convex.

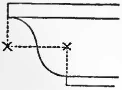


Fig. 126.

The Reverse Ogee or Cyma Reversa (Fig. 127) is composed of the same parts as the Ogee, but reversed, the convexity being in this case uppermost.

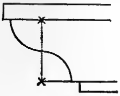


Fig. 127.

The curves composing the two last-mentioned mouldings may be either quadrants, as in the figures struck from the centres marked, or the moulding may be varied according to taste, by using flatter curves.

The Scotia is a moulding chiefly used for bases and constructed thus:—

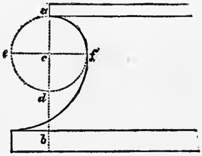
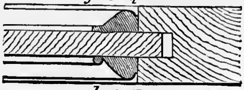


Fig. 128.

In Fig. 128 trisect *a b* in *c* and *d*; from centre *c*, with radius *c a*, describe the circle, *a e d*, a quarter of which forms the upper part of the moulding; draw *c e* at right angles to *a b*, cutting the circle in *e*; from centre, *e*, with radius, *e f*, describe the curve, *f b*, forming the lower portion of the moulding.

When mouldings are formed by a combination of parts of well-known form, they are distinguished by names expressing the combination of those parts.

Thus the moulding at A in Fig. 129 is known as "*Quirk Ovolo and Fillet*," being made up of these three parts, *q o f*.



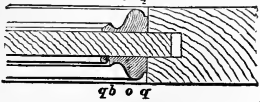


Fig. 129. Scale, 2 inches = 1 foot Fig. 130.

The moulding at B in Fig. 129 is a "*Quirk Ovolo and Bead.*"

In Fig. 130 the moulding at C is a "*Quirk Ogee;*" that at D is a "*Quirk Ogee and Quirked Bead.*"

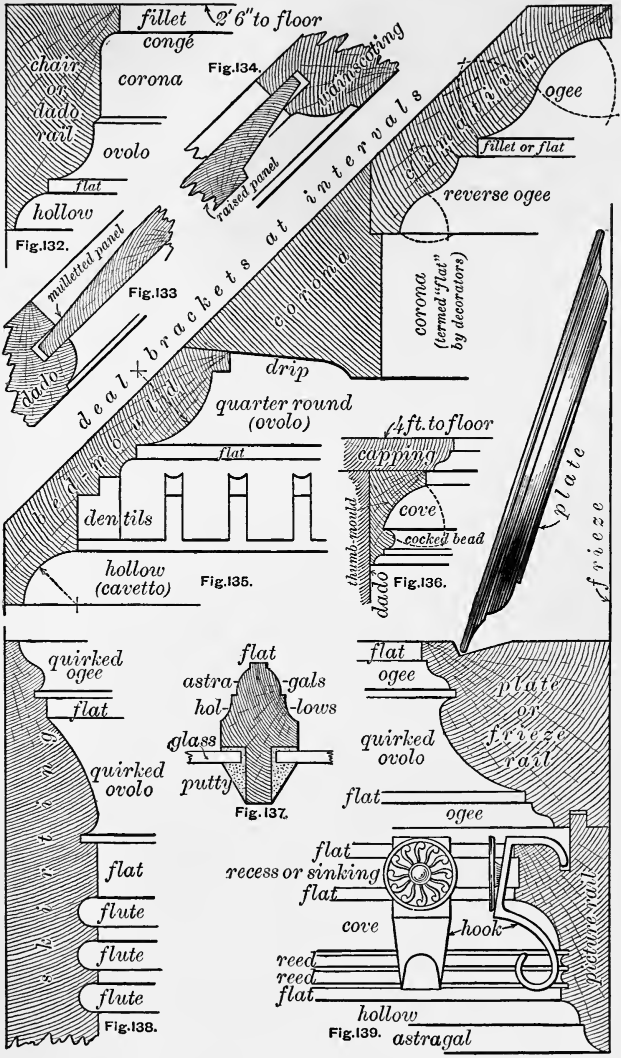

fillet
2' 6" to floor
congé
chair or dado rail
corona
ovolo
flat
hollow
Fig. 132.
mulletted panel
dado
Fig. 133
Fig. 134.
wainscoting
raised panel
deal brackets at intervals
cymatium
ogee
fillet or flat
reverse ogee
corona
corona (termed "flat" by decorators)
drip
bed-mould
quarter round (ovolo)
flat
dentils
hollow (cavetto)
Fig. 135.
4ft. to floor
capping
cove
cocked bead
thumb-mould
dado
Fig. 136.
plate
frieze
quirked ogee
flat
skirting
quirked ovolo
flat
flute
flute
flute
Fig. 138.
flat
astra- -gals
hol- -lows
glass
putty
Fig. 137.
flat
ogee
quirked ovolo
plate or frieze rail
flat
ogee
flat
recess or sinking
flat
cove
hook
picture rail
reed
reed
flat
hollow
Fig. 139.
astragal

PLATE III.

The above are only a few of the commonest classical mouldings, besides which there is an infinite variety belonging to Gothic and other styles of architecture, and new ones are constantly being designed. At one time they were all formed by hand; and it was therefore important to know how to construct the various forms, but they are now nearly always made by machinery.

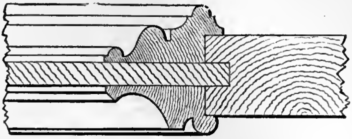


Fig. 131. Scale, 2 inches = 1 foot.

Bolection Mouldings are those which project beyond the face of the framing, as in Fig. 131. They are used in order to give a massive appearance and heavy decoration without increasing the thickness of the framing.

Plate III. illustrates on a scale of half full size the application of mouldings to various constructions in joinery. Figs. 132 to 136 are from an eighteenth century building, and Figs. 137 to 139 modified from the moulding books of Messrs. Elliott of Newbury.

JOINTS.

In this section it is proposed to describe some common forms of joints, which do not form a part of the Elementary Course, and therefore were not referred to in Part I.

The "arrises" or corners of all angle joints in good work should be kept as sharp as possible.

Angle Joints.—MITRE JOINTS.—When the length of the joint is not great the pieces are cut to a bevel, so that the plane of the joint bisects the angle; this is called the "mitre."

This joint depends entirely upon the glue unless it is strengthened by a slip feather, as dotted in Fig. 140.

If the boards are of different thicknesses the joint is made as in Fig. 141.

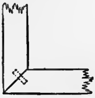


Fig. 140.

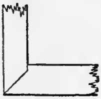


Fig. 141.

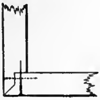


Fig. 142.

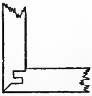


Fig. 143.

Fig. 142 is a modification of the above; it is a good joint for exterior angles, and can be nailed both ways.

This joint is useful for connecting angles such as those of dados or skirtings.

In Fig. 143 the parts are kept together by the form of the joint itself, but it requires a great deal of labour, is very liable to split, and not often used.

Keyed Mitre Joint.—A mitre joint is frequently keyed for strength by inserting thin slips of hard wood covered with glue, as shown in Fig. 144. These may either be horizontal as at K, K, or inclined as at K_1.

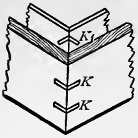


Fig. 144.

A keyed mitre is most generally used for joints visible only on the inside, as the keys are unsightly.

Butt Joints.—In mitre joints the shrinkage of the boards in width, as dotted, does not open the external angle of the joint, though the inner angle does open slightly, as shown by the dotted lines in Fig. 145.

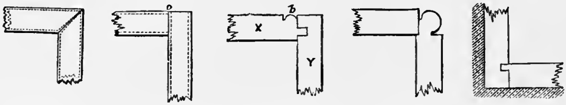


Fig. 145. Fig. 146. Fig. 147. Fig. 148. Fig. 149.

When, however, one piece is *butted* against the other, the piece that has its grain parallel to the plane of the joint is drawn away from the other as it contracts, leaving an opening at *o* (Fig. 146).

To hide this opening by its shadow a bead is often "stuck" on to the piece, as shown at *b*, Fig. 147.

Or in angles exposed to injury, such as those of chimney breasts, passages, etc., a bead is formed so as to avoid the sharp arris (Fig. 148).

This forms what is called a *staff bead.*

Interior angles, such as those of dados or skirtings, may be formed with a simple joint as in Fig. 148. In this case the opening caused by shrinkage is not visible (except on the top edge, which is generally mitred as far down as the depth of the moulding), as it is covered by the wall.

The above joints, slightly modified, are all applicable to acute and obtuse, as well as to right angles.

A common joint for uniting the angles of cisterns or troughs is shown in Fig. 150.

When the angles on both sides are seen, one piece may be housed into the other, as in Fig. 151.

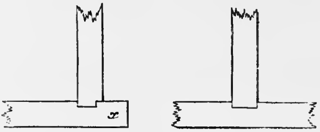
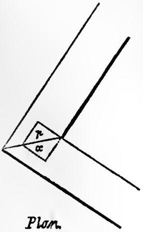


Fig. 150. Fig. 151.

If the end, *x*, cannot be left on, the tongue must be made smaller as in Fig. 149, so that sufficient wood may be left on the outside for strength.

DOVETAIL JOINTS.—*The common Dovetail* has already been described in Part I.

The Mitred or Secret Dovetail is chiefly used by cabinetmakers for highly-finished drawers and boxes, when for the sake of appearance it is desirable that the dovetails should not be visible. In this joint not much more than half the thickness of the boards is dovetailed, the outer portion (*s t*, Fig. 153) being mitred as shown, so that the dovetails may not show on the sides of the exterior angle.



Plan.
Fig. 152.

In order, further, that the dovetails may not be visible upon the upper surface of the boards to be united, the top of the joint is mitred right through the thickness of the board, *a c*, for a short depth (from *a* to *b*). This may also be done on the lower surface if that is likely to be seen.

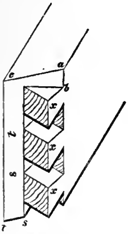


Fig. 153.

Fig. 153 shows only one of the boards to form the angle, but the construction of the other will be readily understood, as it is cut to fit into the projections and indentations of the one shown. The spaces between *x x x* in the figures are the *sockets*, the corresponding projections on the opposite board being called the *pins*

This joint is not so strong as the common dovetail.

The Lap Dovetail is a joint in which the pins on one board, B, do not extend entirely through the thickness of the board A, but are concealed by a portion of the board which is not cut through. In this case, of course, the pins of the board A only are visible.

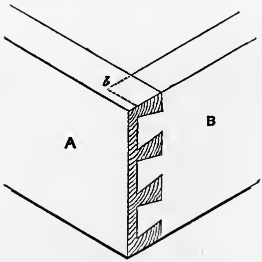


Fig. 154.

This joint is well adapted for the fronts of drawers. The piece, A, which forms the front shows no dovetails, while B forms the side in which their appearance is of no consequence, as it is not seen except when the drawer is open.

KEYS.—When plain surfaces of boarding of considerable extent

are required, as in dados, window backs, wall linings, etc., the boards are generally ploughed and tongued and joined with glue.

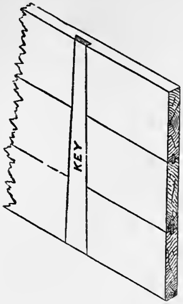


Fig. 155.

Tapering pieces of wood called "keys," very well seasoned, are often let into a wide dovetailed groove across the back, as shown in Fig. 155.

These keys keep the surface of the boards in the same plane, and allow the work to shrink and expand according to the weather.

The edges of boards to be united are sometimes rebated at the back of the joint, and strips of wood are glued in, so as to keep the edges close together. Boards so secured must be very well seasoned, or they will split.

Double Dovetail Keys are small pieces of hard wood, of double dovetail shape, let in, with the grain, across the joint to be secured.

Hammer-headed Key Joint.—When a heavy circular-headed frame consists of several curved pieces, the parts are often kept together by keys of hard wood, of the shape shown at H K in Fig. 156, glued in.

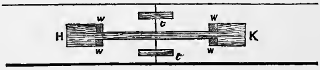


Fig. 156.

If the pieces are very wide, a cross tongue, *t*, is put in on each side of the key, and the joint is tightened up by wedges, *w w*.

Screw bolts may be substituted for the keys, the cross tongue still being used.

Clamping.—Boards are sometimes kept tight together at the ends by a "clamp" (C C, Fig. 157) running across them, grooved

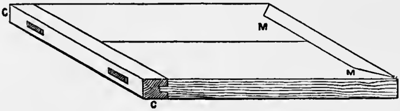


Fig. 157.

on the edge to receive a tongue left on the boards, which are thus free to shrink in width. In the best work tenons are also formed on the ends of the boards, which fit into mortises formed in the clamp.

In some cases the boards are cross-grooved, and the clamp tongued

Mitre Clamping.—When it is advisable, for the sake of appearance, to conceal the ends of the clamp, they are mitred back, as shown at M M, Fig. 157.

Glued Joints.—When it is required to glue large pieces together, the wood should be thoroughly dry, the edges well warmed at a fire, and clean,—the glue as hot as possible.

While the edges are warm they are covered with a coating of glue, and rubbed together, so that the superfluous glue is squeezed out. In intricate corners, and places hard to get at, this may be sponged off at once, but generally it is better to leave it to get cold, as it excludes the air and enables the glue to set more firmly.

Glue is required principally in putting framed work together, and in panels; but the less of it that is used the better, even in fixing.

Two boards may be glued edge to edge, forming a simple butt joint, or their junction may be strengthened by being grooved and tongued as well as glued.

A considerable surface is often covered with boards so united, as in window backs, dados, etc. In such cases keys are generally grooved in across the back, as shown in Fig. 155. These keep the surfaces of the boards in the same plane, and allow them to shrink and expand with changes in the weather.

Glued and Blocked Joint.—Two boards at an angle may not only have the joint between them glued, but may also be strengthened by a block glued into the angle, as at *bl* in Fig. 158.

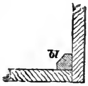


Fig. 158.

Such a construction is called a *glued and blocked joint.* Examples of its use are given at page 117, in the connections of the treads and risers shown in Fig. 220.

For all sorts of curved surfaces small blocks are glued together, and then covered with a veneer.

Sometimes wood is bent to the form required, and then blocks are glued on to the back to keep it so.

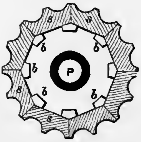


Fig. 159.

In order to avoid using large pieces of timber, which can never be so seasoned throughout as to prevent splitting, columns and similar constructions are built up with thin staves, *s s*, of dry wood, the required support being afforded by an iron column, P, within; and small blocks, *b b b*, are glued inside the joints to strengthen them, as in Fig. 159.

Fixing Joiners' Work.—All joiners' work that is not framed should be fixed so as to be free to expand or contract.

In boarding generally, this may be effected by fixing one edge, and forming the other with a groove and tongue; or the board may be fixed in the centre, with both edges free.

For example, the upper edge of the skirting in Fig. 175 is fixed to the "ground," but the lower edge is free to move, the joint between it and the floor, which would open as the skirting shrinks, being covered by the tongue along the bottom of the skirting which enters the groove formed in the floor. If the skirting board were not thus free to move it would split as it became seasoned.

Again, it will be seen that the frame of the window back (Fig. 175) is free at the lower edge.

The dado in Fig. 163 is also fixed at the upper edge only.

N.B.—In the figures illustrating this section the parts are marked with the following distinctive letters:—

A . . Architrave.
B . . Bracket.
b . . Batten.
ba . . Backing.
bl . . Back lining of sash frame.
bk . . Blocks or blockings.
br . . Bottom rail of sash.
bw . . Weight to balance bottom sash.
C . . Capping.
c . . Cradling.
D . . Dado.
f . . Fillet.
g . . Ground.
H . . Head of sash frame.
h . . Hinges.
SS . . Stone sill.
SL . . Stone lintel.
SF . . Solid frame.
sb . . Sash bar.
sk . . Skirting.
t . . Throating.
tl . . Top lining.
tr . . Top rail of sash.
ib . . Inside bead.
il . . Inside lining of sash frame.
l . . Laths.
mr . . Meeting rails.
ol . . Outside lining of sash frame.
os . . Oak sill.
P . . Plaster.
Pp . . Pocket piece.
p . . Pulley.
pb . . Parting bead.
ps . . Pulley style.
psl . . Parting slip.
RA . Relieving arch.
s . . Styles.
SB . . Surbase.
tw . . Weight to balance top sash.
WB . Wood bricks.
wb . . Water bar.
wp . . Wood plug.
WL . Wood lintel.
WiBd . Window board.
x . . Wedge.
y . . Do.
zps . . Zinc parting slip.

Grounds are pieces of wood nailed to plugs, wood bricks,[1] breeze fixing blocks, or slips in the wall, so as to form a firm basis to which the more ornamental portions, such as architraves, linings, etc., may be fixed.

Grounds are used round the margins of openings not only to receive the linings and architraves, but to form a solid finish to the plastering.

[1] Wood bricks, slips, plugs, etc., have been described at page 10, Part I.

Mitred or Splayed Grounds have the side next to the plastering splayed or bevelled as shown in Fig. 160, so as to form a key for the plaster and secure the joint. This term is often used for grounds which are of a splayed form in plan, such as that in Fig. 178.

Grooved Grounds are those which have the inner edge grooved instead of splayed, to answer the same purpose, *i.e.* that of affording a key for the edge of the plaster.

Examples are given in Fig. 161, and several other figures.

When the joint between the ground and the plaster is covered by an architrave, the splay or groove on the edge of the ground is often omitted, as in Fig. 166. It is, however, better to have it, to form a key for and to secure the plaster firmly until the architrave is fixed.

Finished or Wrought Grounds.—In most cases the ground is rough, its surface being flush with that of the plaster on the walls, and concealed by the architrave fixed to it: sometimes, however, either the whole or part of the surface of the ground is exposed to view; it is then said to be "finished," and is wrought, beaded, or otherwise ornamented.

Fig. 173 shows an example, in which the whole of the ground is visible. In Fig. 177 only part of the ground is seen, which forms the fascia of an architrave, and is embellished by mouldings attached to it.

Framed Grounds are used as margins for openings in superior work.

They form a sort of rough frame, generally concealed from view, and consisting of two upright sides or posts mortised to receive a head terminating in haunched tenons.

Backing.—In order to form a firm support to the lining between the grounds, cross pieces are dovetailed in between the uprights of the adjacent frames, as shown in elevation in Fig. 169 and in plan in several figures; these are firmly attached to wood bricks, whose edges may be seen in elevation behind them (see Fig. 169).

Common Grounds.—In very common work the grounds consist only of the upright posts or styles, and are not framed into a head at all; in other cases a head is provided, but the styles, instead of being framed, are merely halved or notched into it.

Fixing Grounds.—The grounds should be fixed before the plastering is commenced; they form a "screed" or guide, to which the surface of the second coat is floated (see p. 182).

It is therefore important that the grounds should be solidly and accurately fixed, their surfaces and edges should be perfectly true, and so firm that they will not be easily disturbed by the plasterers.

In fixing grounds the face of the ground should project about $\frac{3}{4}$-inch from the naked wall, if it is to be rendered or plastered; or the same distance from the battens, if it is to be battened, lathed, and plastered.

The inner edges of grounds for door and window openings should be kept perfectly plumb, and equidistant from the centre line of the opening, the face of the ground being parallel to that of the door or sash-frame.

The width of such grounds will depend upon their finish; also upon the nature of the opening.

If with linings, the grounds may be from 3 to 6 inches wide, the linings being attached to their edges (Fig. 174). If the grounds are wrought, the architrave or fillet covering the junction of the plaster with the ground may lap over about half the width of the ground (Fig. 174). When boxings are used the grounds will be of sufficient width to contain the shutter and back-flaps required, and may be wrought (Fig. 177) or covered with a double-faced architrave (Fig. 178).

Several examples of grounds are given in pages 81 to 93, and there described, so that it will be unnecessary to enter upon them further in detail at present.

Architraves are borders fixed round the openings of doorways or windows for ornament, and also to conceal the joint between the frame and the plastering.

These borders may be of almost any pattern or dimensions to suit the character of the room.

They are sometimes covered with elaborate mouldings, or made in the form of a pilaster.

The mouldings of the architrave may extend down to the floor as in Fig. 164, or they may rest upon blocks or plinths as in Fig. 168.

The architrave should never be fixed until the plastering is completed and quite dry. It should then be placed so as well to cover the joint (see Fig. 171).

Grounds fixed to the wall are generally provided to form a support to the architrave, and are covered by it (see Fig. 171). But in some cases, as already mentioned, the ground itself forms

the face of the architrave, as in Fig. 172, or in inferior work it may serve all purposes, as shown in Fig. 173.

In order to save labour, and to avoid large pieces of timber, architraves are generally built up in parts glued together. Examples of this will be seen in Figs. 171, 181.

These parts generally consist of a flat portion or base, which is merely a board, beaded, or otherwise ornamented, on edge, and called the face. This is surmounted by mouldings according to taste.

Larger architraves are formed of pieces of different thicknesses tongued together, as in Fig. 166. Those made by machinery may, however, be procured all in one piece.

Double-faced Architrave.—When the base of the architrave is not of equal thickness throughout, but stepped back in the centre, as shown in Fig. 178, it is said to be "*double-faced.*"

Skirtings.—The *Skirting*[1] is a board from 6 inches to 18 inches wide running round the base of the wall of a room. It is intended to cover the junction of the floor with the walls, and also for ornament.

The skirting board may be square or plain, ornamented by a bead or moulding *stuck* upon it (Fig. 160), or by a detached moulding (Fig. 163) it may be sunk to form a double plinth similar to that in Fig. 161. The skirting may be plugged close up to the wall, or fixed to grounds.

These grounds are rough battens nailed to plugs in the wall, and they should be dovetailed at the angles. A narrow horizontal ground, plugged to the wall, runs close behind the top of the skirting; and, if the latter is wide, blocks, placed about 9 inches apart, extend from the floor to this horizontal ground. Such a skirting is seen in Fig. 160, and another in Fig. 162, where it forms the base of a "dado;" a portion of the skirting is stripped off in order to show two of the blocks supporting it.

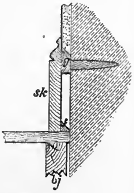


Fig. 160.
Scale, 1 inch = 1 foot.

The lower edge of the skirting is sometimes housed into the floor, as in Fig. 161, or tongued, as shown in Fig. 163; or it may rest upon it, as in Fig. 160; in either case a fillet, *f*, may be added to cover the joint at the back, though this is not absolutely necessary when it is let into the floor. To save material the fillet may be splayed, *i.e.* made of triangular section (Fig. 160).

[1] Sc. *Base*, if mouldings are run upon it.
„ *Base plate*, „ „ separate.

When the floor is uneven the lower edge of the skirting must be scribed to fit it—that is, a line is drawn upon it parallel to all the irregularities of the surface of the floor, and the lower side of the skirting is cut to this line.

The skirting boards should be tongued (or dovetailed) at the internal angles of rooms and mitred, as shown in Fig. 142, at external angles,—in either case the top edge of the joint is mitred right through. The skirting boards should also be tongued wherever they are pieced in length.

The hollow behind the skirting harbours vermin, and the plastering should always be continued down to the floor so as to fill it up (Fig. 162).

The boards of skirtings, as in all joiners' work, should be fixed so as to allow of contraction and expansion without splitting.

This may be done by fixing one side of the board, and tonguing and grooving the joint on the other edge.

Several examples of ordinary skirtings may be seen in the figures illustrating other parts of joiners' work, both in this volume and in Part I., some of which have just been referred to.

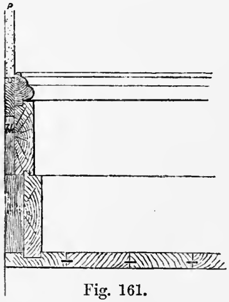


Fig. 161.
Scale, 1 inch = 1 foot.

A Double Skirting consists of two skirtings, one above the other, as in Fig. 161. The width of both skirtings may be equal as in the illustration given. The lower one is sometimes wider than the other, or it may be narrower, according to taste.

Skirtings are often formed in cement and moulded, but such constructions do not come within the province of the joiner.

Dado and Surbase.—For the sake of ornament, and to prevent the wall from being injured by chairs knocked up against it, a moulded bar, called a "chair rail," is sometimes fixed at a height of about 3 feet from the floor, and parallel to the skirting.

This rail should be fixed to a narrow horizontal ground, and should be wide enough to cover the grounds and their junctions with the plastering.

The interval between the rail and the skirting is called the *Dado*, D in Fig. 162, and the chair rail, SB, is called the "*surbase*" of

the dado—the skirting forming the "*base*" B, or, as it is sometimes called, the *plinth.*

The dado may be either panelled, simply boarded, or formed only by the surface of the plastered wall, as in Fig. 162.

Fig. 162 shows a chair rail or surbase, SB, and plastered dado, D, with wooden "base" or "skirting," B.

The chair rail and the upper moulding of the skirting are nailed to narrow grounds, *g g*, Fig. 162, fixed to plugs inserted in the wall.

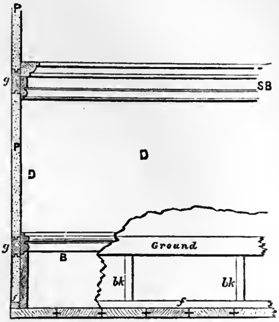


Fig. 162. Scale, ½ inch = 1 foot.

A portion of the skirting is broken away to show the blockings, *bk*, supporting it as described at page 80.

The dado illustrated in Fig. 163 is entirely of wood, being formed of wide boards, grooved and feathered, and hung by thin tongues of hard wood, *j*, at intervals of about 3 feet, to the narrow ground, *g*, which supports the surbase, SB. The boarding is strengthened and kept together by taper keys, *k*, similar to that described at page 75.

The keys may be about 3 feet apart.

The boarding of the dado is thus suspended from the upper "ground," and is free to expand and contract without opening the joints.

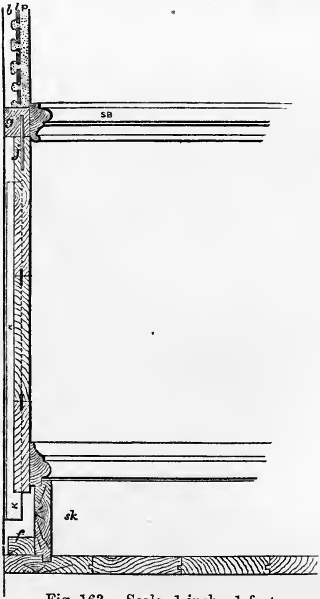


Fig. 163. Scale, 1 inch = 1 foot.

LININGS.

Linings are coverings of wood so placed as to conceal or ornament portions of the interior of buildings. There are several varieties of linings, distinguished by technical names denoting the position in which they are fixed.

All linings should be of narrow boards, ploughed or grooved and tongued, or rebated; free to expand and contract, and nailed to battens fixed to the wall about 2 feet apart.

In superior rooms the linings may be framed and panelled as described at page 177, Part I.

LININGS TO DOORWAYS.—*Jamb Linings* cover the sides of the jambs or openings through walls, such as doorways.

Soffit Linings are those which cover the soffit or under sides of the arch or lintel spanning over a door, or the interior of a window opening.

WINDOW LININGS are differently named according to their position.

Breast Linings are those that cover the portion of the wall between the inside ledge or window board and the skirting. These are more commonly called "*window backs.*"

Elbow Linings cover the splays of the wall between the inside ledge or window-board and the skirting when there are no shutters (see Fig. 174).

Back Linings are those at the back of the recesses for shutters (Fig. 177). This name is also given to that side of the boxing in a cased sash frame which is opposite the pulley stile (see p. 198, Part I.)

The Outside and Inside Linings are those forming the outer and inner sides respectively, of the boxings in cased sash frames.

Wall Linings are of the same nature as the above, but cover the whole surface of the walls.

Jamb and Soffit Linings.—In doorways the sides or "*jambs,*" J J, and the "*soffit,*"[1] S S, of the opening are generally boarded over or lined for the sake of appearance.

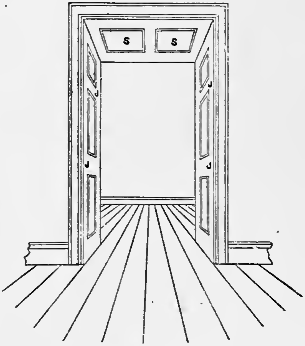


Fig. 164.

[1] Sometimes called *Jamb-head.*

This boarding is called the jamb and soffit linings. These linings serve to conceal the rough sides and soffit of the opening beyond the recess containing the frame. If more than 9 or 10 inches wide they should be panelled, moulded, or otherwise made to correspond in appearance with the face of the door.

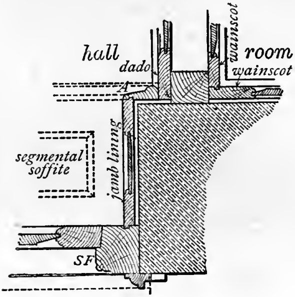


Fig. 165.

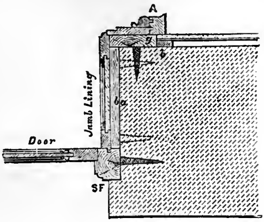


Fig. 166. Scale, $\frac{1}{2}$ inch = 1 foot.

Jamb Linings to external Doorway.—It has been mentioned that external doors are nearly always hung in solid frames. If the doorway is in a thick wall, and for any reason it is required to keep the door near the front of the wall, there remains a considerable depth of the opening behind it which may be lined.

Such cases are shown in Figs. 165, 166. The lining in these examples is very simple, consisting merely of a 1-inch framed, moulded and square, panelled lining, flush at back, tongued into the door frame at one end, and at the other butting against the architrave A. The lining in Fig. 166 is supported by a rough backing fixed to plugs in the wall.

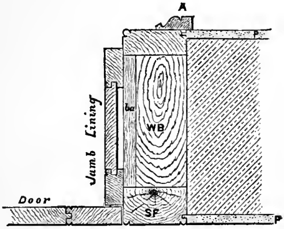


Fig. 167. Scale, 1 inch = 1 foot.

Solid Frames with Jamb Linings for internal Doorways.—In this case the jamb lining is kept back from the edge of the frame a space equal to the thickness of the door, thus forming a deep rebate into which the latter may shut.

The lining is fixed as before to a rough backing, *ba*, which is secured to wood bricks or slips in the wall.

This is a very strong way of hanging a door, but is expensive and seldom adopted for interior doors, unless very heavy and substantial work is required.

The solid frame may be beaded or chamfered on both edges and itself form the finish of the doorway, as at SF, Fig. 167; or the joint between it and the plaster may be covered by an architrave, as at A on the opposite side.

The lower ends of the frame may be tenoned into the floor, which keeps it very firm.

Jamb Linings with framed Grounds.—This is the most usual way of hanging a door in ordinary work.

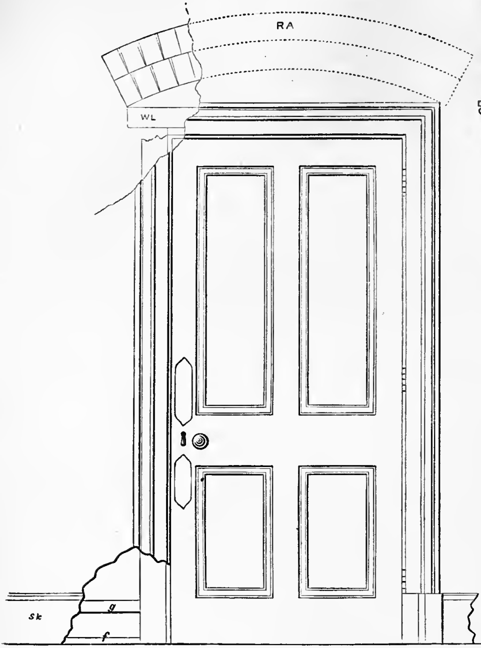


Fig. 168. *Elevation.*

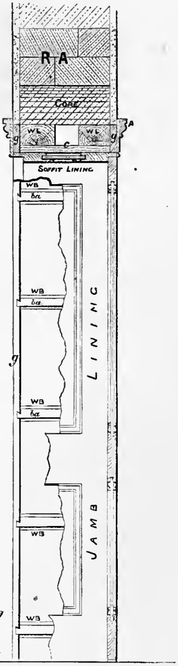


Fig. 169. *Section.*

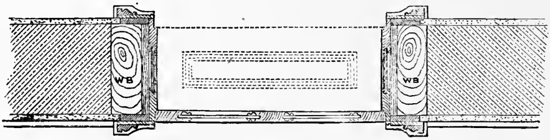


Fig. 170. *Plan.*

Figs. 168-170. Scale, ½ inch = 1 foot.

Figs. 168, 169, 170 give an elevation, cross-sectional elevation, and plan respectively, of a four-panelled interior door, with jamb

and soffit lining of this kind. Fig. 171 shows a portion of the plan enlarged.

In this case it will be seen that the door is hung to the jamb lining itself; the latter is attached to a backing, *ba*, dovetailed in between the framed grounds, and secured to wood bricks in the wall, the edges of which may be seen in elevation in Fig. 169.

In some cases the grounds are tongued into the jamb linings, but this is very seldom done.

The jamb linings go right through the depth of the opening, and on one side of the wall have their edges rebated to receive the door; the edges on the other side of the wall being (in superior work) similarly rebated to correspond.

The soffit lining is secured to cradling or backing, *c*, consisting of rough battens attached to the under side of the lintels over the opening.

Of course the doorway might be spanned by a rough axed arch, or by a concrete beam, without wood lintels, in which case the cradling would be secured to plugs let into the arch or beam, unless the beam were made of coke breeze concrete which will admit and hold nails.

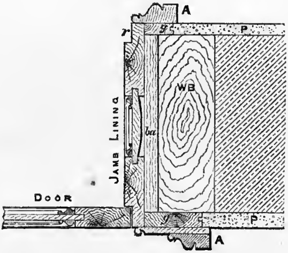


Fig. 171. Scale, 1 inch = 1 foot.

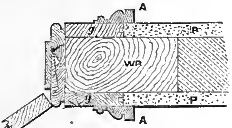


Fig. 172.
Scale, 1 inch = 1 foot.

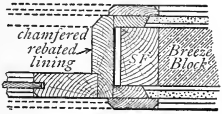


Fig. 172*a*.

The enlarged plan in Fig. 171 differs slightly from Fig. 170, inasmuch as a smaller architrave is shown on the inside of the doorway. The panelling of the soffit lining is often shown in dotted lines upon the plan of the doorway.

Fig. 172 shows the jamb linings, with framed and finished grounds for a doorway in a thin partition wall. In practice, however, a solid frame would be preferable as in Fig. 172*a*. It would run up and be secured to the joists over.

Jamb Lining with finished Grounds.—In common work—to save the expense of architraves—the grounds may be wrought so as to present a finished appearance, and themselves form an ornamented margin to the opening.

In Fig. 173, g is a wrought and chamfered ground secured to the backing ba, which is plugged to the wall. It will be seen that g acts both as a ground and as an architrave. This is taken from an actual case, but has little to recommend it, as the ground really forms only a feeble sort of door frame.

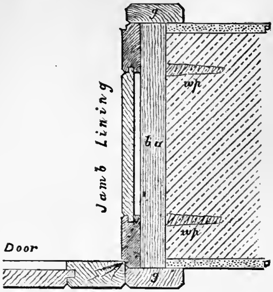


Fig. 173. Scale, 1 inch = 1 foot.

Single and Double rebated Linings.—Single-rebated linings are those having a rebate formed to receive the door, but none on the other side of the wall. In superior work there is a similar rebate formed on the opposite side, as at r in Fig. 171, and the lining is said to be *double-rebated*.

Window Linings.—Figs. 174, 175 give a half-plan and a section of a window with cased frame and double-hung sashes, furnished with panelled and moulded linings.

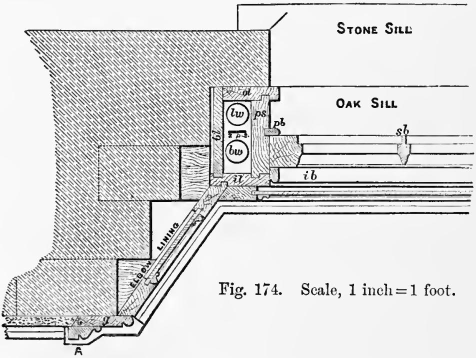


Fig. 174. Scale, 1 inch = 1 foot.

It will be noticed that the head of this window is not cased as in the illustrations given of windows without linings (Part I.), but is solid, being secured to the cradling c attached to the under side of the lintels, WL, its inner end being grooved to receive the tongued extremity of the soffit lining, the other end of which is nailed to the ground.

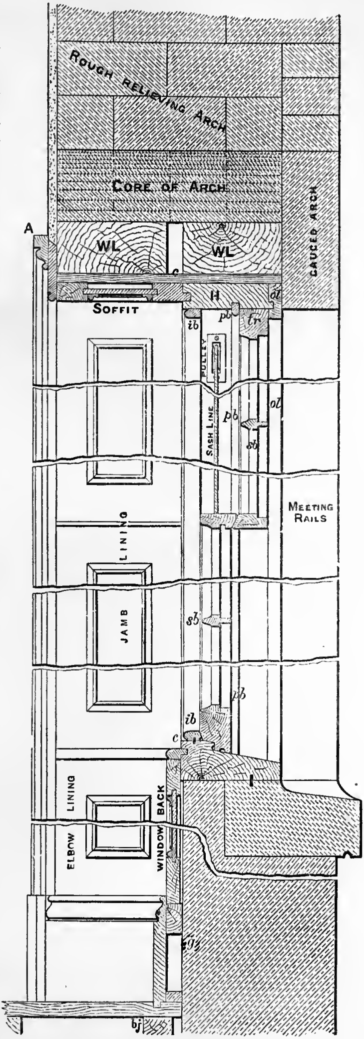
The jamb lining is grooved at one end into the inside lining of the boxing, and at the other nailed to the projecting framed and finished ground which forms the face of the architrave.

It is supported by being nailed to the splayed wood brick, WB.

The upper rail of the window back is secured to the oak sill, being surmounted by a capping *c*. The lower rail rests upon the ground *g*, the joint being covered by the moulding of the skirting,[1] so that the expansion and contraction of the window back are not prevented.

The jamb lining is here shown as finished to look like shutters, sometimes described as "*sham shutters.*" When the lining is narrow it is often merely a plain board, tongued if the width requires it, wrought on face, but not framed; when moulded it is made to correspond in appearance with the doors or other panelled work of the room.

The wood brick, WB_1, is inserted in this case, so that the boxed frame may be nailed to it obliquely through the inside lining, *il*, but it is generally considered sufficient to drive a wedge in between the back lining and the wall.



Vertical section through centre of Fig. 173.
Fig. 175. Scale, 1 inch = 1 foot.

[1] In practice it is more usual to frame the window back and elbows with flush beaded skirting: (1) To avoid the difficulty of stopping the projecting skirting against the architrave; (2) In order to make the framing from floor upwards in one piece. The flush bead ranges with the top of the ordinary skirting.

SHUTTERS.

Windows, especially those of ground-floors, are frequently fitted with shutters for security and warmth at night.

Inside Shutters are fixed on the inner side of the wall of a building.

Outside Shutters are fixed on the outer side of the wall.

Inside Shutters are hung in several different ways, which may be generally arranged under two heads.

1. *Folding.*—In leaves, hinged together and folding back into recesses or "*boxings*" prepared for them.

2. *Sliding.*—In leaves, sliding up and down, and counterbalanced by weights in the same way as sliding sashes; or sliding *laterally* upon rollers in and out of recesses formed for them at the sides of the window.

Folding Shutters.—A recess or boxing for these is formed in the space between the inside lining of the sash frame and the framed ground at the back of the architrave.

The back of this recess is plastered in common work, but in better work it is covered by a lining, called the "back lining."

This back lining has one end tongued into the inside lining of the sash frame, and the other housed or tongued into the ground behind the architrave.

In Fig. 177 the architrave is fixed to a finished ground into which the back lining is grooved.

As the interior of the boxing is exposed to view when the shutters are closed, the back of the ground is sometimes covered, for the sake of appearance, by a return lining such as that marked *l* in Fig. 178.

The leaf which is exposed to view during the day may be framed and panelled like the doors of the room, and is called the *shutter*, the remaining leaves are called the *back flaps.*[1]

The back flaps, if they exceed 6 or 7 inches in width, are framed, but may be of a plainer description of panelling, or sometimes not panelled at all.

In most of the accompanying illustrations the shutter and flaps are shown as framed square on the outer side and bead flush on the inner side. The inner side is often finished bead butt for the sake of economy; or the flaps are often framed square

[1] Sc. *Backfolds—Closers.*

on both sides, or moulded on one or both sides according to the class of work.

In the very best work, however, the shutters and flaps are all made the same on both sides, so that when closed they will all appear alike, whether seen from the interior of the room or through the glass from the outside.

In hanging shutters the knuckle of the hinges of the front leaf should be about half-an-inch from the inner angle of the inside lining—so that the whole width from one extremity of the shutters to the other, when they are open, is an inch more than the width of the window opening.

The flaps are connected by small "back-flap" hinges fixed as shown, or by butt hinges attached to the edges of the flaps. In the former case the shutters, when folded back, are kept apart by nearly the thickness of the hinge, and there is room for an iron bar or other fastening to hang between them.

Shutter and One Flap.—When the opening is narrow, or the wall of considerable thickness, the shutter may be hung in two leaves, as in Figs. 176, 177.

Fig. 176 is an interior elevation of a window with sliding sashes fitted with shutters hung in two leaves. The shutter and

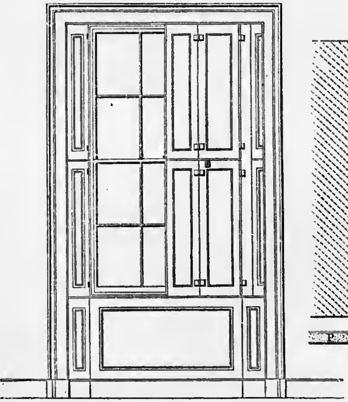


Fig. 176. Scale, ¼ inch = 1 foot.

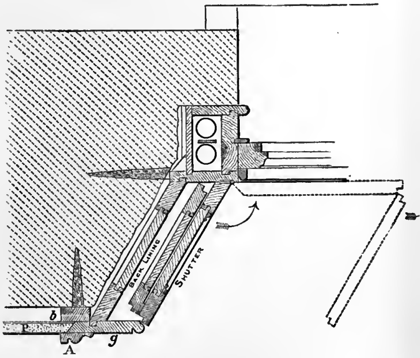


Fig. 177. Scale, 1 inch = 1 foot.

flap to the right of the elevation are closed, the other shutter and

flap being folded back into the boxings, as shown in the half-plan Fig. 177.

The shutter is moulded on the side exposed to view during the day; the back of this shutter and that of the back flap (which are seen together on the inside of the room when the shutters are closed) are bead flush, while the front or outer side of the back flap is framed square.

In this and some of the following figures the dotted lines show the position of the shutters and flaps while in the act of being closed.

Shutter and Two Flaps.—When a window opening is wide, or the wall in which it is formed is not very thick, there is not so much room for shutters in proportion to their width, and they have to be folded into a greater number of leaves in order that they may take up less room in the thickness of the wall.

Fig. 178 is the half-plan of a window with the same opening as that in Fig. 177, but in a wall only 1 foot 6 inches, instead of 2 feet thick.

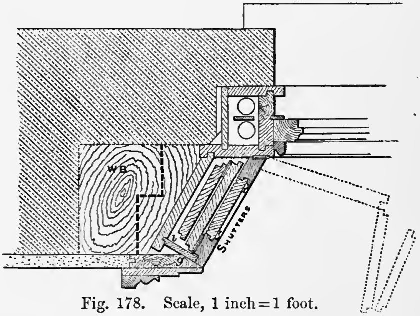


Fig. 178. Scale, 1 inch = 1 foot.

The shutter in this case is necessarily folded into three leaves; the two back flaps being very narrow are not framed.

The lining, *l*, at the back of the ground, *g*, is only to preserve a neat appearance within the boxings when they are empty; it may be omitted and the back lining of the boxing prolonged to meet the back of the ground.

There are many methods of arranging folding shutters, which vary considerably according to the length of shutters required—and the space available for them to fold into.

One method of gaining room for shutters is to make the boxings project into the room, as shown in Fig. 179, or when the

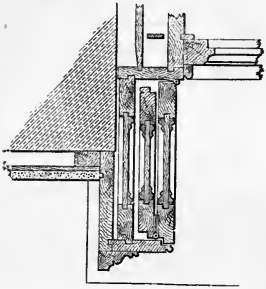


Fig. 179. Scale, 1 inch = 1 foot.

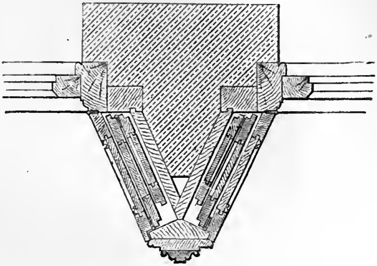


Fig. 180. Scale, 1 inch = 1 foot.

windows are separated by very narrow piers, the shutters may be arranged as in Fig. 180.

Where the masonry cannot be made to extend inwards far enough to form a support for the lining at the back of the shutters, such support is afforded by wooden brackets fixed to the back of the pier and extending inwards as far as may be required.

Another arrangement for shutters to cover a window in a thin wall is shown in Fig. 181.

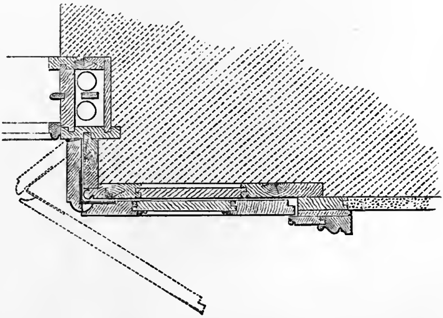


Fig. 181. Scale, 1 inch = 1 foot.

In this case the larger flap of the shutter folds back upon the inner side of the wall, and is exposed to view, being connected with the boxing of the window by a short flap which forms the jamb

lining. The elbow of the wall is lined, in order to present a neat appearance when the shutters are closed.

This is rather an old-fashioned arrangement, but very useful in some situations.

Shutters with Cover Flap.—The different forms of folding shutters hitherto illustrated have one disadvantage in point of appearance, viz., that when the shutters are closed the recess formed to receive them is visible, and forms a break in the continuity of the panelling.

To avoid this, in very superior work the recess is covered by a separate flap, X (Fig. 182), which is hinged to the ground supporting it. When the shutters are to be closed, this flap is opened; and after they are shut against the sash the flap is returned, so that the appearance of the lining is preserved intact.

In order to throw the shutters back into the recess sufficiently to clear this flap, various arrangements are adopted.

That shown in the figure simply consists of a hinge, *h*, of peculiar form attached to a heavy moulding fixed to the inside lining of the cased frame. The action of this hinge will be clear upon examining the figure, in which the shutters are shown folded back into the recess, the position, X_1, of the flap, when partly closed, being indicated in dotted lines.

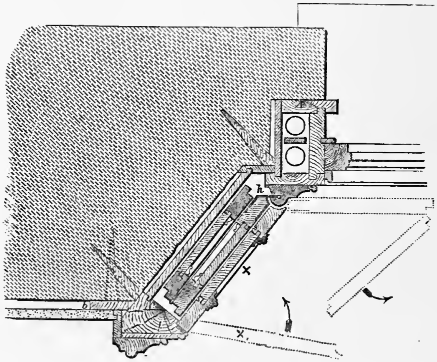


Fig. 182.[1] Scale, 1 inch = 1 foot.

In some cases the shutter is thrown back clear of the covering flap by inserting a very short flap,[2] which lies across the ends of

[1] Modified from Plate 54, vol. iii., Laxton's *Examples of Building Construction.*

[2] A good example of this arrangement is shown in Laxton's *Examples of Building Construction,* Plate 55, vol. iii.

the shutters nearest the sash frame, and answers the same purpose as the peculiar hinge shown in Fig. 182.

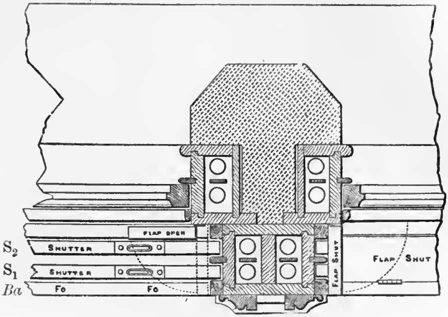


Fig. 183. Scale, 1 inch = 1 foot.

SLIDING SHUTTERS may move either vertically or laterally, in the former case they are often called *lifting shutters.*

Lifting Shutters are hung in exactly the same way as sliding sashes; immediately behind the boxed frame of the sash is a similar frame for the shutters (Fig. 183).

The leaves of the shutters slide down into a rectangular well formed for them in the floor, so that their upper rails are nearly level with the window sill.

On the front side they lie close to the inside of the wall, and on the other they are screened by a framed *back* (*Ba* in Fig. 184).

The two leaves of the shutter slide in different and parallel paths,—the upper one, S_1, between the bead on the front lining of the shutter frame and the parting bead; the other, S_2, between the parting bead and a bead fastened on to the inside lining of the sash frame.

The shutter nearest to the wall, S_2, is the lower of the two when they are closed. It is somewhat larger than the other, being of such a height that it will extend from the top of the flap or capping to the upper edge of the meeting rail. The other shutter fills up the space between the upper edge of the meeting rail and the top of the window.

The top of the well is closed when the shutters are down by a horizontal hinged flap, and vertical flaps conceal the parting bead, etc., when the shutters are not closed.

Sliding shutters are useful when there is not a sufficient thickness of wall behind the sash to receive folding shutters.

Fig. 183 is a plan of part of two adjacent windows separated by a narrow pier or mullion, and fitted with lifting shutters, and Fig. 184 is a vertical section of the same.

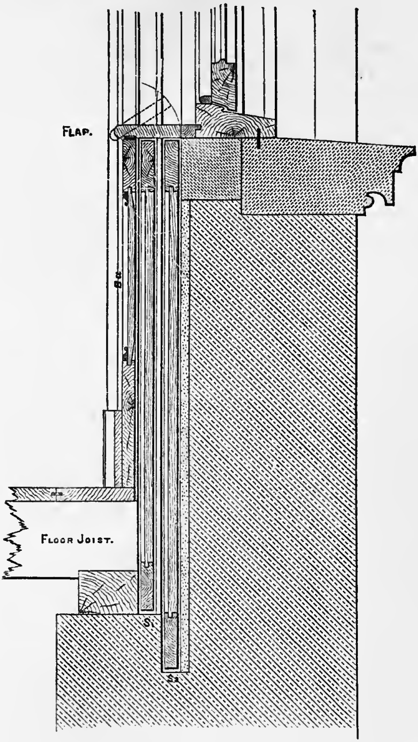


Fig. 184. Scale, 1 inch = 1 foot.

On the left of the plan the flap over the well for the shutters is supposed to be standing vertically open along FO FO, so that the upper rails of the shutters are visible with the flush handles for lifting them.

The vertical flap is also open and folded back.

On the right of the figure both flaps are closed.

In some cases the boxing for shutters is so arranged that its outside lining is formed by the inside lining of the cased frame for the sashes, which is a more economical construction than that shown in Fig. 183, but not so convenient.

Sliding Shutters are those in which the flaps slide laterally into recesses formed on each side of the window.

Such an arrangement can only be adopted when there is a considerable space on each side of the window. It possesses no particular advantages, and cannot here be described.

A good illustration of shutters sliding laterally will be found in Laxton's *Examples of Building Construction*, vol. iii., Pl. 37.

Outside Shutters for dwelling-houses are generally hung somewhat like doors—in two leaves, one on each side—which are fixed to the outside lining (or to a fillet plugged to the wall in front of the outside lining) with *parliament hinges*, by which it is enabled to clear the reveal, and fold back upon the wall; see Fig. 185.

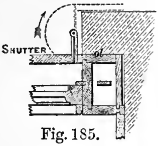


Fig. 185.

For shop fronts shifting shutters are used, the appearance of which is familiar to all. Any description of them would be beyond the range of these Notes.

SKYLIGHTS AND LANTERNS.

Skylights are windows, either fixed in roofs, or themselves forming the roof of a staircase or other building lighted from above.

They are very varied in form, according to the position in which they are fixed.

In many cases the skylight is raised upon vertical or slightly inclining frames filled in with sashes which form its sides (Figs. 190, 191); it is then frequently called a *Lantern*.

The most common form of skylight is perhaps that in which the sash is parallel to the slope of the roof, and slightly raised above the surface of the slating as in Fig. 186.

An opening is formed in the slope of the roof (by trimming the common rafters CR), of the same size as the proposed skylight; a lining[1] is attached to the inner sides of the trimmers TT, and of the trimming rafters, extending a few inches above them. Upon this the sash rests; its styles and rails project over the

[1] Usually called a "*curb*" or "*kerb*," and dovetailed at the angles.

frame, and may be rebated to fit it, or a projecting piece may be nailed on, as shown at *c* in Fig. 186, to cover the joint.

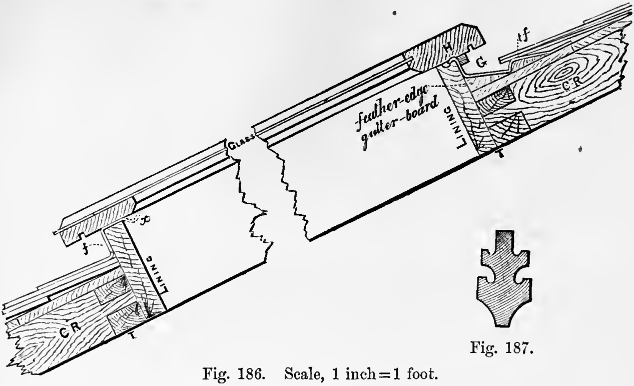


Fig. 186. Scale, 1 inch = 1 foot.

Fig. 187.

Lead flashings, *ff*, are also fixed as shown to prevent the wet from getting in ; and any that may penetrate finds itself in a groove *g* cut in the upper surface of the top and side linings, down which it runs, escaping at the lower end of the latter.

The sash bars run down the slope of the roof like rafters, and should be made strong enough to resist the weight of glass and snow, force of wind, etc. The rebates should be grooved, so as to carry off any moisture that may pass round the edges of the glass.

The lead apron at the lower extremity of the inside of the skylight should be formed into a sort of gutter, as shown in dotted lines at *x*, to receive and carry away the moisture which condenses on the lower surface of the glass. It is also desirable to form gutters in the sides of the sash bars for the same purpose, as in Fig. 187.

The panes should run continuously through from top to bottom of the skylight, without cross bars to intercept the wet running off the glass.

If it be necessary to have the panes in shorter lengths, they should overlap, as in Fig. 188, and be secured by metal clips, shown in thick black lines which hang the bottom edge of each pane to the top edge of the pane below it.

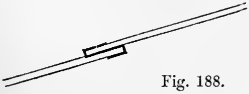


Fig. 188.

It is sometimes necessary, for want of space, to obtain more light, or for other reasons, to make the side linings vertical instead of at right angles to the rafters as shown, but the latter is the stronger construction.

It is becoming usual, especially where a skylight is of considerable length, to avoid the gutter by lowering the head H of the skylight 2 or 3 inches below the lower edge of the slates of the roof. The end at *x* remains at the same level, so that the slope of the skylight is flatter than that of the roof.

If such a skylight as that shown in Fig. 186 be required to open it must be hinged at H; and in some cases the joint is protected by a strip of lead fastened round the sash, which hangs down over the lead flashing on the sides of the frame.

The glass in skylights is sometimes secured by means of a capping fixed to the upper surface of the sash bars, which holds the glass more firmly and prevents the wet from penetrating.

Another kind of skylight consists of a pair of sashes fixed above the apex of a roof and parallel to its sides.

Two varieties, surmounting a queen-post roof, are shown in Figs. 189, 190.

The skylight, of which half is shown at A, consists of a pair of sashes similar in construction to that just described, raised a few

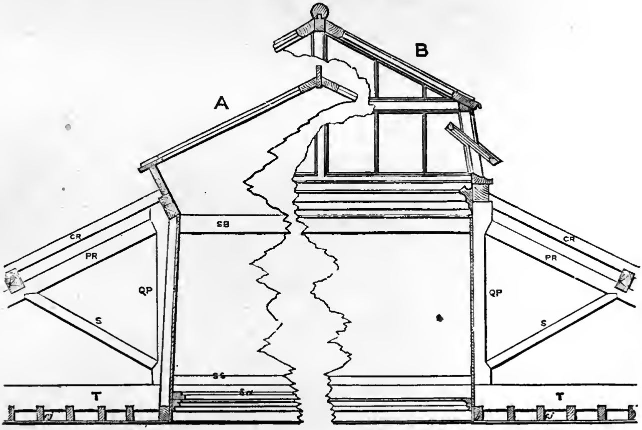


Fig. 189. Scale, $\frac{1}{8}$ inch = 1 foot. Fig. 190.

inches above the surface of the side slopes of the roof by means of linings fixed to the purlins resting upon the queen posts.

The inner sides of the queen posts have backing pieces fixed to them, carrying a lining so as to convert the interval immediately under the skylight into a shaft or boxing.

In some cases, for the sake of appearance, the lower extremity of this shaft is filled in with a sash, *Sa*, called a *counter skylight* or *ceiling light*, containing glass, so as to keep the plane of the ceiling almost unbroken.

The skylight or lantern at B is raised two or three feet above the roof by means of framed sides containing sashes, which may either be fixed, or made to open by being hinged at the top, or (as in Fig. 190) hung on centres.

The sill of the framed sides is fixed to a capping or curb, which rests upon a cross bearer supported by the heads of the queen posts.

This form of skylight gives more light and ventilation than that at A, but is of course considerably more expensive.

Fig. 192 shows a skylight or lantern over a room covered by a lead flat.

This example is taken from the lecture-theatre of an hospital near London, but is in many particulars similar to one over the Museum of Economic Geology, and illustrated in Laxton's *Examples of Building Construction.*

The lantern being large and heavy is supported on two sides by cast-iron girders, AB, CD (Fig. 192), extending across the room. The other sides are covered by binders fixed between these girders.

Fig. 192 is a plan showing the arrangement of these girders, and of the binders and joists supporting the lead flat, the larger portion of which is broken away to show the bearers beneath.

Fig. 191 is a sectional elevation of half the lantern, showing the different parts in sufficient detail to render much explanation unnecessary. The moisture condensed upon the inside of the upper portion of the skylight runs down and is caught in a small zinc gutter formed in the upper portion of the moulding at W, and from thence is led through a hole (dotted in the figure) to discharge upon the lead flat outside.

The details of the side sashes hung on centres are similar to those already given for such sashes in Fig. 315, Part I.

It will be noticed that the inside bead, *x*, Fig. 191, is so fixed upon the sill that the skylight when closed does not shut up against it, but an interval is left, which forms a gutter to receive the condensed moisture from the sash. A groove cut in the sill enables this water to escape.

Such a lantern as that shown in Fig. 191 may itself form the roof of a staircase, in which case the oak sill, forming the base of the sash, would rest upon the coping of the walls of the staircase.

When the side sashes of a lantern are fixed, ample provision should be made for carrying off the moisture which condenses on the inside of the glass, and has a tendency to run down into the room below.

This may be prevented by providing a wide oak sill projecting

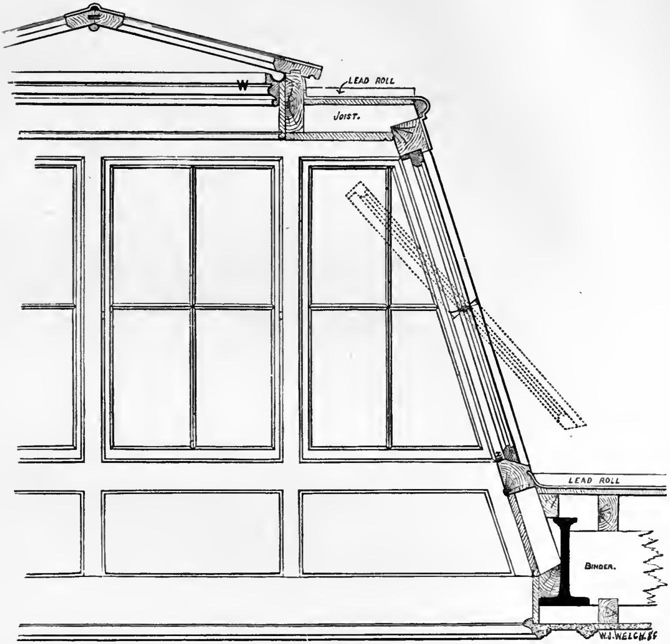


Fig. 191. Scale, 1 inch = 1 foot.

inwards an inch or two, so as to give room for a deep groove formed on the inside, into which the condensed moisture runs, and from whence it is led outwards by holes bored through the sill.

Or the inside bead on the oak sill may be kept a little back from those on the sides, so as to form a gutter as explained above and shown in Fig. 191.

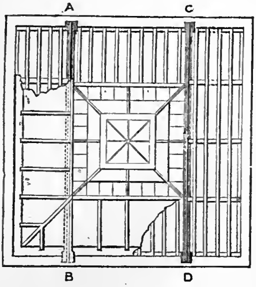


Fig. 192. Scale, $\frac{1}{12}$ inch = 1 foot.

Sliding Sash in Skylight.—It is sometimes advisable to con-

struct the slightly inclined sashes of a skylight so as to open by sliding.

In such a case it is important to keep the rain from penetrating between the frame and the sash.

This may be done by arranging as in Fig. 193.

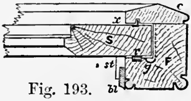


Fig. 193.
Scale, 1 inch = 1 foot.

The sash, S, slides down the frame, F, upon a little brass friction roller, *r*, fixed in the frame. *st* is a stop on the sash which strikes against the block, *bl*, attached to the frame, and arrests the fall of the sash when it has gone far enough.

c is a capping protecting the upper surface of the joint between the sash and frame. As an additional precaution an angle-iron water bar may be inserted as shown, so as to prevent any water running off the sash from penetrating sideways at the point *x*. If, in spite of this, any water should penetrate, it will find itself in the groove *g*, which leads it off through the lower end of the frame.

Chapter V.

STAIRS.

Stairs are arrangements of steps for conveniently ascending and descending from one level to another.

They are generally constructed either in stone, wood, concrete, or iron.

The consideration of iron stairs does not come within the range of these Notes.

The terms common to all stairs will first be mentioned, and also a few general principles universally applicable; after which the construction of stone and wood stairs respectively will be considered more in detail.

The following are terms used in connection with all stairs, whatever may be the material of which they are constructed.

The Staircase is the chamber or space which contains the stairs.

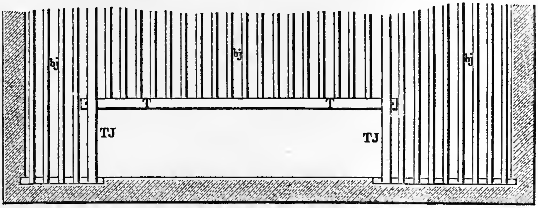


Fig. 194.

This may be a room of the exact size required, the walls of which closely surround and support the steps, as in Fig. 228, or the stairs may be in a large apartment, such as a passage or hall, openings being left in the upper floors so as to allow headway for persons on the steps, and to furnish communication between the stairs and the different stories of the building.

In such a case the stairs are generally, though not necessarily, placed against a wall, as shown in Fig. 194, and the opening is trimmed round in the manner explained at page 91, Part I.

In Factories, or similar large buildings, the staircase should be in a tower projecting from the building, so that it may in case of fire be intact. The best materials for fireproof stairs are, first, wrought iron, then cast iron, then hard wood with plastered soffit. With regard to stone steps, see note, p. 106.

Tread is the horizontal upper surface of the step upon which the foot is placed.

Rise is the vertical height between two treads.

Riser[1] is the face or vertical portion of the step.

Nosing is the outer edge of the tread. In most cases it projects beyond the face of the riser and is rounded or ornamented by a moulding, being known, accordingly, as a "rounded" or "moulded" nosing.[2] (See Figs. 196, 216.)

Fliers are the ordinary steps of rectangular shape in plan.

Winders[3] are the steps of triangular or taper form in plan, required in turning a corner or going round a curve. The small ends of winders are sometimes called the *quoins.*

A Curtail Step is described at p. 126.

A Flight is a continued series of steps without a landing.

A Landing[4] is the flat resting-place at the top of any flight

A Half Space is a landing extending right across the width of the stair.

A Quarter Space is a landing extending half across the width of the staircase.

The Going of a Stair is the horizontal distance from the face of one riser to the face of the next riser, and does not include the nosing or the projection of the tread beyond the face of the riser.

This term is, however, sometimes taken to mean the width of the stair, that is, the length of the steps.

The Going of a Flight is the horizontal distance from the first to the last riser in the flight.

The Line of Nosings is tangent to the nosings of the steps, and thus parallel to the inclination of the stair.

Newels are posts or columns used in some kinds of stairs to receive the outer ends of steps. (See Figs. 223, 224.) The name "newel" is sometimes applied to the final baluster on a curtail step.

When the newels surround a central opening, as in Fig. 226, the staircase is said to have an "*open newel.*"

The Handrail is a rounded or moulded rail, parallel nearly throughout its length to the general inclination of the stair, and at such a height from the steps as to be conveniently grasped by a person on the stairs.

Balusters are slight posts or bars supporting the handrail.

Dimensions of Stairs.—The dimensions of staircases and steps are regulated by the purposes for which they are intended.

Length of Steps.—Sometimes spiral staircases are constructed in very cramped positions, with steps only 1 foot 9 inches long; but, as a rule, steps should not be less than from 3 to 4 feet long,

[1] Sc. *Breast.* [2] Sc. *Bottled* or *Bottle-nosed step.* [3] Sc. *Wheeling steps.* [4] Sc. *Plat.*

so as to allow two people to pass, and in superior buildings they are very much longer.

The stairs in the illustrations given with these Notes are necessarily shown narrow for want of space.

Tread and Rise.—The angle of ascent for a stair will depend upon the total height to be gained between the floors, and the space that can be afforded in plan.

The wider the step the less the rise should be, as steps which are both wide and high require a great exertion to climb.

Authorities differ slightly as to the proportion between the tread and riser; the following table is given by Mr. Mayer in Newland's *Carpenter's and Joiner's Assistant.*

Treads, inches.	Risers, inches.	Treads, inches.	Risers, inches.
5	9	12	5½
6	8½	13	5
7	8	14	4½
8	7½	15	4
9	7	16	3½
10	6½	17	3
11	6	18	2½

The following rule is often adopted for steps of the dimensions ordinarily required in practice, *i.e.* those with treads from 9 inches to 14 inches wide:—

Width of tread × height of riser = 66 inches.

Thus with a tread of 12 inches riser would be 5½ inches; with a riser of 6 inches the tread would be 11 inches.

The rule adopted in France, where they have given great attention to the subject, is as follows:—"Inasmuch as on the average human beings move horizontally 2 feet in a stride, and as the labour of rising vertically is twice that of moving horizontally, the width of the tread added to twice the height of the rise should be equal to 2 feet."

The proportion that the tread and riser bear to one another cannot always in practice be fixed by rule, but is regulated by the space—as regards both plan and height—that can be afforded for the staircase.

The tread of a step should, however, never be less than 9 inches in width, even for the commonest stair; while, for first-class houses and public buildings, the stairs may have treads from 12 to 14 inches wide.

Flights should, when possible, consist of not more than 12 or

13 steps, after which there should be a landing, so that weak people may have a rest at short intervals.

Two consecutive flights ought not to be in the same direction (see p. 130).

DIFFERENT FORMS OF STAIRS.

N.B.—In the Figures connected with stairs the handrail is drawn in the elevations and sections in order more clearly to show the direction of the steps, but omitted from the plans so as not to obscure them.

A Straight Stair is one in which all the steps are parallel to one another and rise in the same direction—thus a person ascending moves forward in a straight line.

Figs. 198, 199, 221, 222, show plans and sections of straight staircases, the former in stone, and the latter in wood; these are described at pages 108, 109.

Such a stair is, for some reasons, very convenient, but can only be used when there is a considerable length of space available for the staircase compared with the height to be gained.

When this is not the case, the flights of steps are made to run in different directions, so that they are doubled up into a shorter space.

Flights running alternately in opposite directions are found to be a great relief in ascending a considerable height, and therefore a very long straight stair is objectionable.

A Dog-legged Stair[1] is so called from its being bent or crooked suddenly round in fancied resemblance to a dog's leg.

In this form of stair the alternate flights rise in opposite directions, as indicated by the arrows in Figs. 200, 203, and 224.

The ends of the steps composing each of these alternate flights are in the same plane with those of the other flight, so that there is no opening or well hole between them.

It is evident that—putting landings out of consideration—dog-legged stairs require only half the length of staircase that would be occupied by an equal number of steps of the same size arranged as a straight stair. On the other hand, the dog-legged stair requires twice the width of the straight stair.

Figs. 200-202 show a dog-legged stair in stone with a half-space landing. Figs. 223, 224 show a similar stair in wood.

[1] This term is generally used with reference to wooden stairs, but there is no distinct name for stone stairs of similar form. Stairs with rectangular well holes, such as those in Figs. 208, 216, are sometimes called *dog-legged.*

In Fig. 203 there is no intermediate landing, the whole space being taken up with winders.

It will be noticed that all the winders converge to a point in the stair itself, so that they are very narrow near this end, and most inconvenient to ascend. This is a great drawback to the dog-legged form of stair, which, indeed, should never be used when winders are required, if there is room for a well hole between the flights.

A Geometrical Stair is one in which there is an opening or well hole between the backward and forward flights.

Such a stair requires of course a little more width, but only about the same length of space as a dog-legged stair.

The effect of the well hole is that the winders converge to a point between the flights, and have a certain amount of width even on the verge of the well hole. At a short distance inwards, where the person ascending places his foot, the winder is so broad as to afford a very convenient tread.

Figs. 205-207 show a geometrical stair in stone without intermediate landings, the space being occupied entirely by winders. Fig. 228 shows a similar stair constructed in wood.

Circular Stairs are composed of steps contained in a circular or polygonal staircase, towards the centre of which they all converge.

All the steps are necessarily winders.[1]

A CIRCULAR NEWEL STAIR is one in which the converging steps are supported by a newel at the centre of the staircase.

This newel may be either solid or hollow (see page 112).

A CIRCULAR GEOMETRICAL STAIR is in form the same as the last described, but that there is no newel. The steps converge as before, but rise round an open well hole instead of resting upon a newel (page 113).

STONE STAIRS.

Stone Stairs have an advantage over those of wood, inasmuch as they are much simpler in construction,[2] but the steps are heavy and require substantial walls for their support; moreover they become smooth under the friction of continued wear, and then are slippery and dangerous.

Stone Steps are generally solid blocks, and should be worked on

[1] Sc. *Wheeling steps.*

[2] Hanging stone steps are soon destroyed by fire; the part exposed to the heat expands, that imbedded in the wall does not, hence the steps snap off at the wall.

the tread and rise, the former being for external steps slightly weathered, or the stone set with a slight inclination outwards.[1] In superior buildings the soffit also is worked, and the nosing may be moulded,[2] as shown in Fig. 196.

Steps and landings that cannot be got out in one stone must be of pieces jointed, joggled, and plugged together; in some cases it is necessary to support the landings on girders. Stone steps are sometimes formed with thin flags forming treads and risers, similar to those of wooden steps. Such steps require no further description. The following remarks refer to solid steps.

SQUARE STEPS are rectangular in section, as shown in Fig. 195.

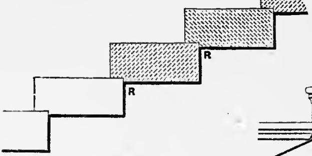


Fig. 195.

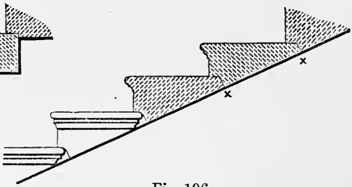


Fig. 196.

The hatched portion of these figures is in section, the remainder in elevation.

SPANDRIL[3] STEPS have the lower side cut away so as to form a raking soffit, as in Fig. 196; this is sometimes useful where headway is required under the stairs, it also makes the steps lighter, and is considered to have a better appearance.

FIXING STONE STEPS.—Stone steps may in some forms of staircase be supported at both ends by walls; in other cases one end only of each is built into the wall; these latter are called *hanging steps.*

The lowest step of a stair is sometimes sunk slightly into the ground to prevent it from sliding on its bed.

Steps supported at both ends are of most simple construction. The stone is rectangular in section, of a height exactly equal to the rise, and in width a little more than that of the tread (Fig. 198).

They are about 12 inches longer than the width of the stair, so that a length of 6 inches at each end is built into the adjacent walls.

When, however, these walls do not rise higher than the sides of the stair, the steps are of a length exactly equal to the width of the stair, and the ends are supported by walls built underneath them.

[1] Sc. this inclination is called the *kilt* of the stone. [2] Sc. *Bottled* or *Bottle-nosed.*
[3] Sometimes called Feather-edged steps.

Hanging Steps are each fixed at one end only; the outer end projects and is without support other than that afforded by the steps below it.

The fixed ends of hanging steps should be let into the wall about 9 inches, and very solidly and firmly built in.

As each step is supposed to depend to a certain extent on the support of the step below it, the joint between the two is so made that the pressure may be transmitted from one step to the other, and the parts in contact may be kept from slipping.

In square steps this is often done by cutting a rebate[1] (R R, Fig. 195) along the lower edge of the front of each step, into which fits the upper edge of the back of the step above, or a deeper rebate may be formed along the lower edge of the breast of each step, and the back-joint cut off at right angles to the soffit, as shown at Y Y in Fig. 197.

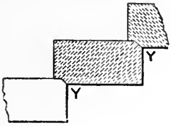


Fig. 197.

If the ends of the steps are securely built into the wall the steps cannot slide, and the rebate is of very little use; in fact, in the very best work it is sometimes omitted, unless the steps have a low rise, and would otherwise be too thin to bear the weight upon them, in which case their thickness can be increased by introducing the rebate.

A plain chamfered joint at right angles to the soffit, like that in Fig. 197 but without the rebate, is sometimes used.

Hanging steps may be built in as the wall is carried up; or, to avoid risk of damage to the steps, indents about 9 inches deep may be left in the walls, and the steps inserted afterwards; they should be pinned in with cement, and iron packing of hoop iron, pieces of old saws, etc.

Sometimes about 12 inches of the walling above and below the steps is built in cement.

Different Arrangements of Stone Stairs.[2]—STRAIGHT STAIRS.—Figs. 198, 199 show a straight stair composed of square steps supported at each end by being built into the side walls.

Fig. 199 is a horizontal sectional plan (looking downwards) through step No. 12.

The steps have 9 inches tread, and 7 inches rise, and between the flights (each consisting of 9 steps) is placed a landing.

[1] Sc. *Piend-Check.* [2] Figs. 198-214 are on a scale of $\frac{1}{8}$ inch = 1 foot.

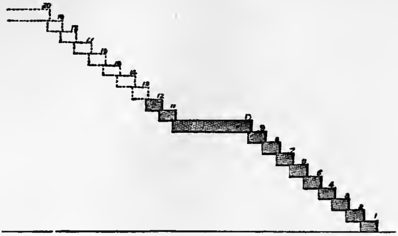


Fig. 198. *Section.*

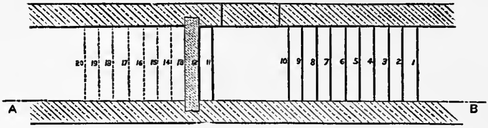


Fig. 199. *Plan.*

Dog-Legged Stairs in stone[1] are generally composed of hanging steps, the inner ends of which are firmly built into the walls

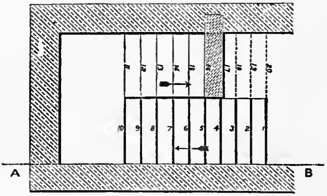


Fig. 200. *Plan.*

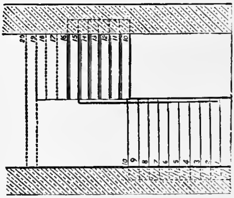
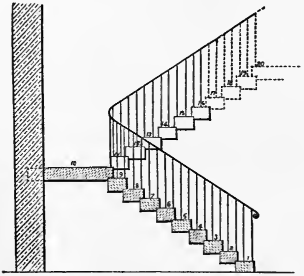


Fig. 202. *Elevation.*



Sectional Elevation on A B.
Fig. 201.

of the staircase, while the outer ends of one flight are in the same plane as those of the other flight.

Fig. 200 is a sectional plan (looking downwards) on the sixteenth step. Fig. 201 is a sectional elevation on the line A B, through the lower flight; and Fig. 202 is a front elevation of the stairs, showing the front of the lower flight and the back of the upper flight of steps

[1] See Note, page 104.

The stairs in Fig. 200 are shown with a half-space landing; but if the same height has to be gained when there is a smaller space available for the staircase, winders may be added so as to have only a quarter-space landing, similar to that in Fig. 226, or the whole space may be occupied by winders as in Fig. 203.

Winders would be necessary also in case a greater height had to be gained, without increasing the area of the staircase.

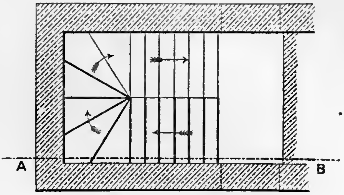


Fig. 203. *Plan.*

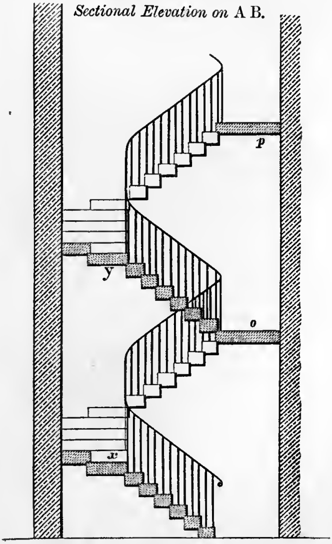


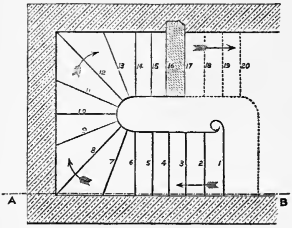
Fig. 204.

Figs. 203, 204 show a dog-legged stair with winders com-

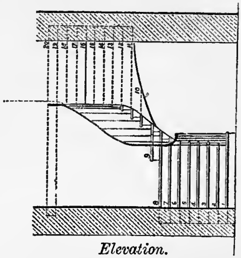
municating between three floors, These figures make clear the importance of having a sufficient headway between the flights running in the same direction (see *x y*), and also between the landings (see *o p*).

A Geometrical Stair in stone consists entirely of hanging steps, the outer ends of which are built into the walls of the staircase, while the inner ends abut upon the well hole of the stair, having no support but that derived from their successive connection, until they reach the floor.

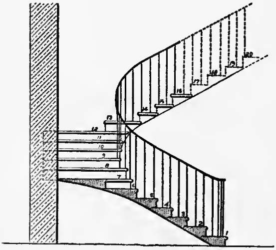
Figs. 205, 206, 207 give illustrations of a geometrical stair



Plan.
Fig. 205.



Elevation.
Fig. 207.



Sectional Elevation on A B.
Fig. 206.

in stone, with a narrow well hole, having a semicircular end. Fig. 205 is a sectional plan made through the sixteenth step looking downwards; Fig. 206 a vertical section through the lower flight, and elevation of the upper flight beyond; and Fig. 207 a front elevation of the staircase, showing the faces of the risers of steps of lower flight, and the backs of the steps of the upper flight.

The stair is constructed with spandril steps, and without a landing, except at the floors, the space being entirely filled with winders, the improved form of which, as compared with the triangular winders of the dog-legged stair, will be evident upon comparing Fig. 205 with Fig. 203.

Fig. 208 shows a geometrical stair adapted for a large and wide staircase.

This stair consists of three flights and two quarter-space landings, besides a large and wide landing (to which the stairs lead) on the level of the floor above.

The position and direction of the steps will be easily under-

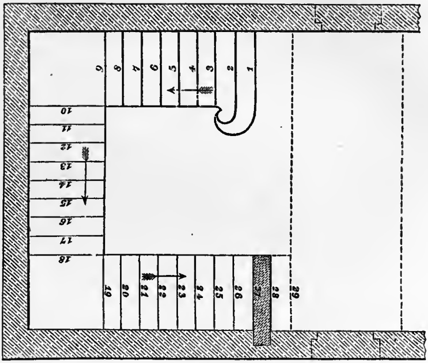


Fig. 208.

stood from the plan, without elevations, sections, or further explanation.

In some cases the inner corners of the quarter-space landings abutting on the well hole are cut off and made in plan of a quadrant shape, by which the curve of the handrail is improved at these points.

Such a stair takes up a great deal of room, and is only suitable for large and important buildings, where sufficient space can be afforded for the staircase.

In Fig. 208 a landing of the whole width of the staircase is shown at the level of the 29th step. Of course, if the arrangements required it, a quarter space landing at this point would be sufficient; from it would lead a flight parallel to steps 10 to 18, and running in the opposite direction.

Circular Stairs in stone may be composed either of steps supported at both ends, or of hanging steps converging toward a well hole; in either case, of course, all the steps are winders.

Circular Newel Stairs consist of square steps supported by the wall at one end, and at the other end by a "newel" or column of masonry, toward which they converge in the centre.

This newel may be either hollow or solid.

Fig. 209 shows an example of a circular stair with a hollow newel, consisting of a brick cylindrical shaft into which the inner

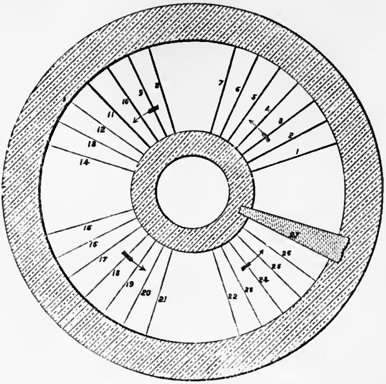
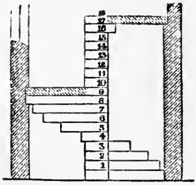


Fig. 209.

ends of the steps are pinned, the other ends being built into the outer wall of the staircase.

In some cases a thin wall is built round the centre newel, and also round the inside of the external wall, to support the ends of the steps, instead of building them in.

A very common construction, especially for circular staircases of small diameter such as those in turrets, is shown in Figs. 210, 211.



SECTION THROUGH *a, b.*

Fig. 210.

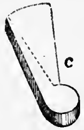
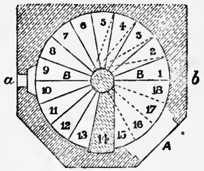


Fig. 212.



SECTIONAL PLAN.

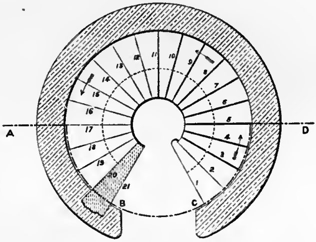
Fig. 211.

Each step is worked in the form shown in Fig. 212, with a

circular portion on the inner end, having a diameter equal to that of the intended newel.

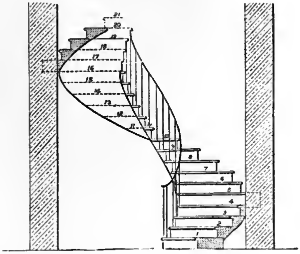
As the steps are built up the outer ends are secured in the wall of the staircase, while the circular portions at the inner extremity, being laid one upon another, give the step the required support, and form the newel of the stair.

Circular Geometrical Stairs consist entirely of hanging winders built into the outer wall of the staircase, and converging toward an open circular well hole down the centre.



Plan.

Fig. 213.



Sectional Elevation on A B C D.

Fig. 214.

Figs. 213, 214 show illustrations of such a stair. Fig. 213 being a sectional plan on No. 20 step, and Fig. 214 a sectional elevation.

The steps are of spandril section, except No. 1, which is necessarily square or it would have a very narrow base to rest upon.

WOODEN STAIRS.

Wooden Steps are lighter than those of stone, and do not require such strong supports. They are also more elastic, and do not become so smooth under wear as to be dangerous.

On the other hand, they are subject to decay, they may be more rapidly destroyed in case of a fire, and may thus cut off all exit from the upper floors.

Letters of reference in the figures connected with wooden stairs :—

Apron lining	*al*	Laths	*l*
Balusters	B	Outer strings	OS
Bearers	*b*	Pitching piece	P
Blocks	*bl*	Plaster	*pl*
Brackets	Br	Riser	*r*
Bridging joists of floor	*bj*	Rough brackets	*rb*
Cross bearers	*cb*	Rough strings	RS
Fillets	*fi*	Soffit joists	*sj*
Furrings	*f*	Tread	*t*
Glued block	*gb*	Trimmer	T
Handrail	HR	Trimming joists of floor	TJ
Joists of landing	*j*	Wall strings	WS

N.B.—The handrails are shown in the elevations in order to make the direction of the steps more plainly evident; but they are omitted in the plans for fear of rendering them obscure. The skirtings are also omitted from the plans. The plaster of the wall is also omitted from both plans and sections of the figures on a small scale.

Parts of Wooden Stairs.—STRINGS[1] are thick boards or pieces of timber placed at an inclination to support the steps of a wooden stair.

Cut Strings.—Wooden stairs of the commonest description are thus constructed.[2]

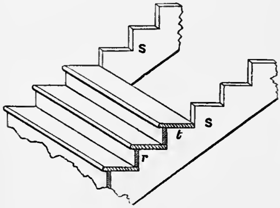


Fig. 215.

Two "*strings*," SS, are fixed at the slope determined upon for the stairs; in these rectangular notches are cut, each equal in depth to the rise, and in width nearly equal to the tread of a step: upon these boards are nailed, forming the treads, *t*, and risers, *r*.

Cut and Mitred Strings.—In stairs of a better description the

[1] Sc. *Stringers.*
[2] Stairs of this construction are never used in ordinary house-building.

outer strings are cut as above described; but the ends of the risers, instead of coming right through and showing on the outer surface of the string, are mitred against the vertical part of the notch in the string, as shown at *aa* in Fig. 217, the other end of the step being, as before, housed into a groove formed in the wall string.

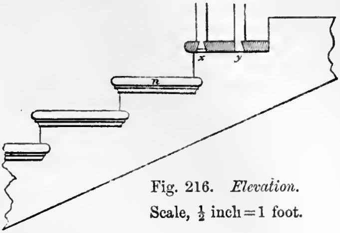


Fig. 216. *Elevation.* Scale, ½ inch = 1 foot.

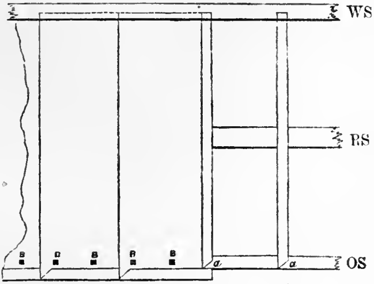


Fig. 217. *Plan.* Scale, ½ inch = 1 foot.

The outer extremity of the tread is also cut and mitred, as shown in Fig. 217, to receive a return moulding, forming the nosing of the end of the step.

BB show the mortises for the balusters, which should be dovetailed into the treads;[1] the dovetails may be formed as at x or as at y, Fig. 218.

Housed Strings.—In many staircases the strings, instead of being notched out to receive the steps, are left with their upper surfaces parallel to the lower, and grooves are cut into their inner sides to receive the ends of the treads and risers; these grooves are called "*housings,*" and the steps are said to be "*housed*" into the strings.

Fig. 219 is an elevation of the inner side of a housed string, showing the sinkings or housings formed to receive the steps.

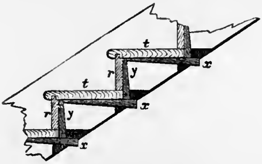


Fig. 218.

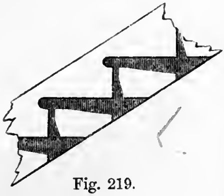


Fig. 219.

Scale, ½ inch = 1 foot.

Fig. 218 is a sectional elevation through the steps, showing the

[1] In speculative work the ends of balusters are simply skew-nailed to the treads or let into them without dovetailing, so that the balusters simply hang from the handrail.

treads, *t*, and the risers, *r*, in position. These are secured by means of wedges, *x y*, which should be well covered with glue before insertion.

The treads are sometimes formed with two tenons at each end, which fit into mortises cut through the string.

Open Strings are those, such as the cut strings, or cut and mitred strings, described above, which are cut so as to show the outline of the steps.

Close Strings have their upper and lower surfaces parallel, the steps being housed into them as above described (see Fig. 218).

A Wreathed String is one formed in a continuous sweep round the well hole of a geometrical stair.

The Wall String is the string up against the wall, and plugged to it. WS, Fig. 225.

The Outer String is the string at the end of the steps farthest from the wall. OS, Fig. 225.

Rough Strings.—With stout treads and risers the two strings above mentioned are sufficient for stairs of 3 or 4 feet in width.

For wider stairs, however, the steps require additional support, and this is afforded by means of one or more "rough strings," or "*carriages*," fixed in the interval between the wall string and outer string, already described.

Two rough strings are shown in Fig. 222, for the sake of illustration, but one only would be necessary in so narrow a staircase; one rough string is shown in Fig. 224.

The scantling for rough strings may be about the same as those for bridging floor-joists of the same length (see p. 101, Part I.)

The rough strings sometimes have small notches on their upper surfaces to receive the back edge of the tread, and their ends are attached to trimming joists TJ (see Figs. 221, etc.), or into pitching pieces P (Fig. 228), or trimmers T (Fig. 222), where trimming joists are not available.

WOODEN STEPS are formed of boards, as shown in Fig. 220.

The risers are united to the treads by joints, which may be grooved and tongued, as in steps 5, 6—feathered as in step 4—or rebated, as No. 3; in every case the joint is glued. The riser often has only its upper end tongued, the lower butting upon the tread below. This is not so good a construction as that shown at 3. A common practice is to house the lower edge of the riser into the tread below, as at *x*. The tread is sometimes tongued into the riser, but that is not a good construction.

The joint between the tread and riser is strengthened by small

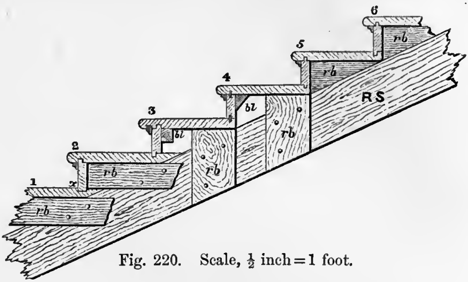


Fig. 220. Scale, $\frac{1}{2}$ inch = 1 foot.

blocks, *bl*, glued into the inner angle, as shown in steps 3 and 4; these may be either rectangular or triangular in section.

The inner ends of the treads rest upon the rough strings, RS (if any), and they are frequently further supported by rough brackets, *rb*, attached to the rough strings or carriages.

These brackets may be pieces nailed alongside the string, as in steps 1, 2, 3, 4, or triangular pieces fixed to its upper surface, as in 5 and 6.

Occasionally vertical brackets are made of a width equal to that of the tread of the step, as at *xy* in Fig. 223.

In some cases a board is notched out like a cut string and nailed alongside the rough string, to answer instead of the rough brackets (see Fig. 227).

The treads project over the risers and are finished with a rounded or a moulded nosing, the projection of the nosing being generally equal to the thickness of the tread. When a moulded nosing is adopted with an open string, the moulding is returned at the end of the step, being mitred at the angle, as shown at Fig. 217.

The mouldings are generally planted on under the rounded nosing of the tread.

The treads should be of oak or other hard wood, and may be $1\frac{1}{8}$ inch thick for steps 4 feet long—the thickness being increased by $\frac{1}{8}$ inch for every 6 inches added to the length of the step.

In very common stairs the risers are sometimes dispensed with.

In some cases, especially in geometrical stairs of a high class,

the upper edges of the risers are dovetailed to the treads, and the back of the treads screwed up to the lower edge of the risers.

Different Forms of Wooden Stairs.—STRAIGHT STAIRS.—In very narrow stairs of ordinary construction, with a wall on one side only, the following is the arrangement usually adopted.

Two grooved strings, OS and WS, Fig. 222, are placed at the required slope, and at a distance apart equal to the length of the steps.

The wall string, WS, is fixed by being plugged to the wall. The ends of the treads and risers are keyed into the housings or grooves worked in the inner and outer strings.

The upper and lower ends of these strings are framed into newel posts, and so are the outer ends of the first and last risers of each flight. When the flight of steps extends uninterruptedly from the lower to the upper floor, these newels are attached to trimming-joists, TJ, provided in the floors to receive them.

When the flight is broken by a landing, additional newel posts are provided on each side of the landing, and extending the full depth between the floors, as in Fig. 221.

To these are secured the trimmers, T, fixed and wedged into the wall, and projecting from it to carry the landing.

As already mentioned, the two strings are sufficient for stairs with stout treads and risers up to a width of 3 or 4 feet.[1]

For wider stairs, however, additional support to the steps is necessary, and this is afforded by one or more rough strings (RS, Fig. 222) or carriages placed in the interval between the strings already described.

The ends of these rough strings are framed or housed into the trimming-joists provided to receive them in the floors, between which the stairs extend.

When there is a landing the upper ends of the rough strings are fixed to the special trimmers which carry the landing.

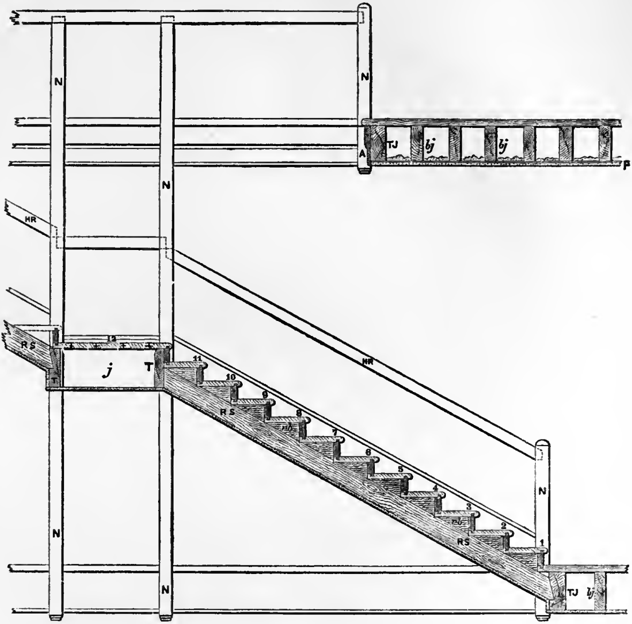
The treads are further supported by rough brackets *rb*, Fig. 221, secured to the rough strings.

The landing itself is formed like a floor, of boards laid upon joists framed in between the trimmers just mentioned.

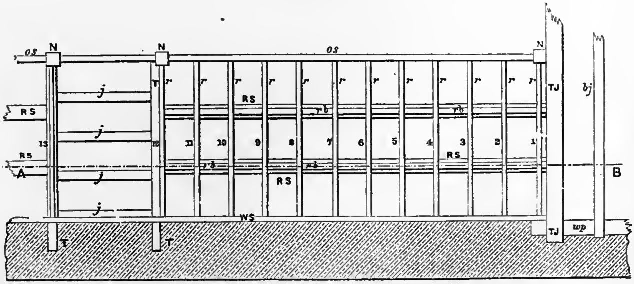
When there is a wall on each side of the steps, of course the newels are not required.

When the floor is continued under the lowest flight of a stair, the space between the soffit of the stairs and the floor is called the *spandril.*

[1] When the outer string is a *cut-string* it is never desirable to omit the carriage, however narrow the stair may be, as it would cause creaking, if not positive weakness. Even when both strings are close a carriage is an advantage.



Section on A B.
Fig. 221.



Plan (with treads and boarding removed).
Fig. 222.

Figs. 221, 222. STRAIGHT STAIRS. Scale, ¼ inch = 1 foot.

This space is often utilised as a cupboard by enclosing it with a panelled front (containing a door, and sometimes a window), known as the *spandril framing.*

Dog-legged Stairs.—Fig. 224 is the plan of a dog-legged stair with a half-space landing. The treads of the steps in the lower flight are omitted, so as to show the strings and risers. A portion of the steps of the upper flight is broken away in order to expose to view the construction of the flight below.

In this stair the wall string, WS, and outer string board, OS, are constructed as before, with intermediate rough strings if necessary.

The outer strings are tenoned into the newels, and so are the first and last risers of the flight.

The outer string of the upper flight and that of the lower flight are in the same vertical plane, so that if the plan of the upper flight were complete the outer string of the upper flight would overlap and hide the outer string of the lower flight.

In the same way, if the number of steps in each flight were the same, the newel, N_3, of the upper flight would in plan exactly cover the newel, N, of the lower flight, being immediately over it.

The handrail in the plan is omitted as before.

Fig. 223 gives the elevation of the upper flight, and the section of the lower flight of the stairs shown in Fig. 224; but no portion of the elevation is broken away, and the treads of the lower flight are shown in section, though omitted from the plan.

The newels are fixed to trimming joists TJ, provided in the floors, and to trimmers T across the staircase at the landing.

The rough strings, RS, are framed in between these trimmers, and rough brackets, *rb rb*, are nailed alongside of them to support the steps.

The tread of the top step is frequently united to the boarding of the landing by a rebated joint. This is advisable if the space below the steps, known as the spandril, is to be made use of as a cupboard. In such a case the landing and the parts of all the steps should be put together with tongued joints, so that dust may be prevented from getting through them. Such joints are often used in superior work even when there is no cupboard below.[1]

Newel Stairs is another name given to dog-legged stairs, because the newels form a conspicuous part of the structure.

[1] It is more cleanly to lath and plaster soffits of stairs even in cupboards.

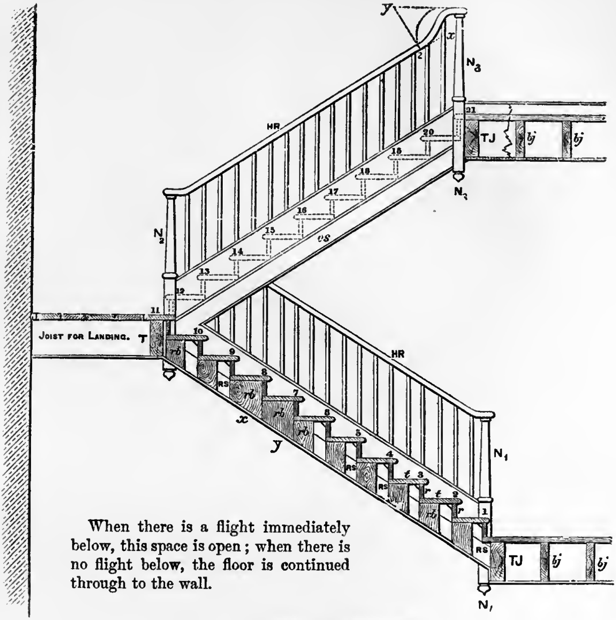
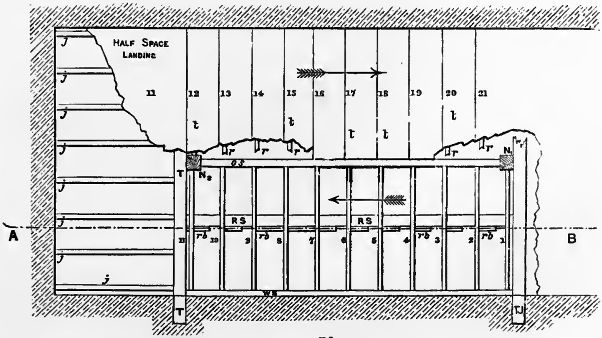


Fig. 223. *Sectional Elevation on* A B.

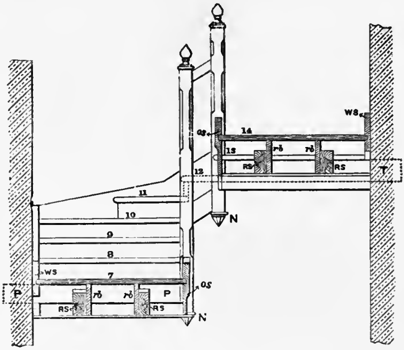


Plan.

Fig. 224.

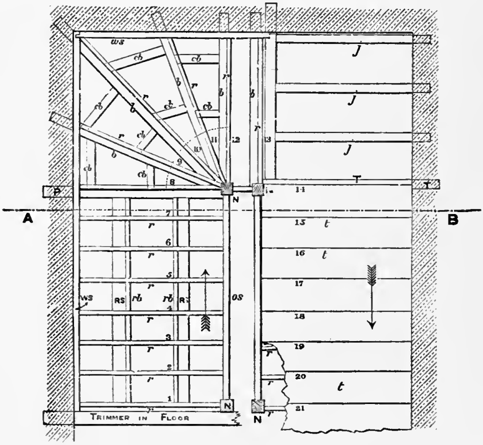
Figs. 223, 224. Dog-Legged Stairs. Scale, $\frac{1}{4}$ inch = 1 foot.

OPEN NEWEL STAIRS have newels arranged round an opening or well hole in the centre between the flights of steps.



Sectional Elevation on A B.

Fig. 225.



Plan.

Fig. 226.

Figs. 225, 226. OPEN NEWEL STAIRS. Scale ¼ inch = 1 foot.

Fig. 226 shows the plan of such a stair, with a quarter-space landing.

The boarding of the landing and the treads of the lower flight are omitted on plan, in order to show the construction below.

Fig. 225 is a sectional elevation on A B. The treads of the lower flight are shown in elevation though omitted from plan.

The construction of the straight portion of the stairs is similar to what has already been described. The winding steps are constructed as follows:—

Bearers, *bb*, carrying the risers, *rr*, are framed into the newels, their outer ends resting in the wall of the staircase. Between them are fixed cross bearers, *cb*. These would not be necessary in a narrow staircase, but are inserted in Fig. 226 for the sake of illustration.

In this example four winders are introduced to show the defects of such an arrangement as pointed out at page 131.

In Figs. 226, 228 the skirting is omitted in that portion of the plan where the treads are shown.

Geometrical Stairs have no newel posts. The flights are arranged around a well hole in the centre—sometimes called an "*open newel*"—and each step is secured by having one end housed into the wall string, the other end resting upon the outer string, but partly deriving support from the step below it.

The handrail is uninterrupted in its course from top to bottom.

The treads for geometrical stairs should be substantial.

The string may be greatly strengthened by a flat iron bar screwed to its under side.

Figs. 227, 228 give a plan and sectional elevation of a geometrical stair with winders.

The portion of the staircase shown in Fig. 228 consists of six fliers, then eight winders, then seven more fliers, making 22 steps, leading to a half-space landing on the floor above; from this the stairs again rise, commencing with the step marked 23, the remainder being broken off to show the first flight.

The treads of the lower flight and winders are also omitted, in order to show the supports below.

The steps are formed in the way described at page 117, with (in this case) feather-tongued joints between the treads and risers.

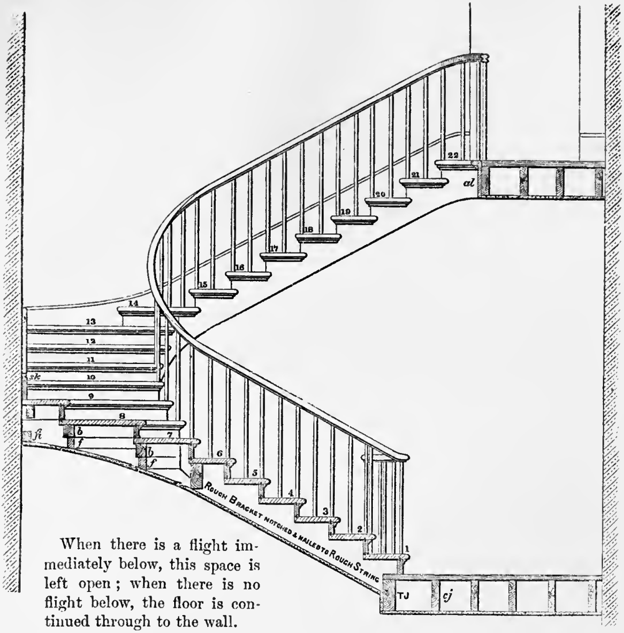


Fig. 227. *Sectional Elevation on* A B C D

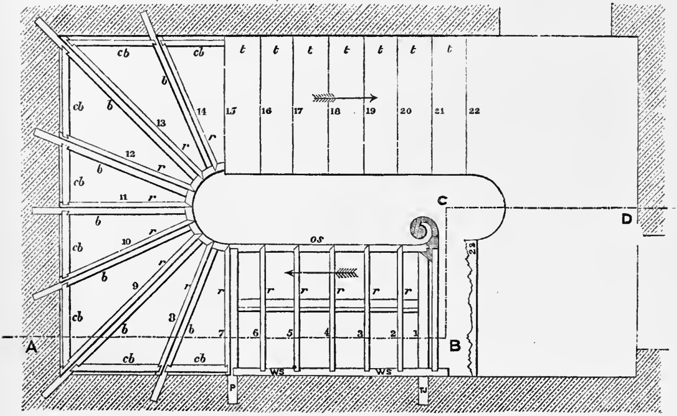


Fig. 228. *Plan.*

Figs. 227, 228. GEOMETRICAL STAIRS. Scale, $\frac{1}{4}$ inch = 1 foot.

The handrail has, as before, been omitted from the plan for the sake of clearness.

The treads and risers are housed into the wall string, the outer ends resting upon a cut and mitred string, and intermediate support is afforded by a rough string, to the side of which is nailed a rough notched bracket, cut to fit the under side of the steps, and to serve instead of brackets.

The strings themselves are framed in between the trimming joists provided in the floors, and *pitching pieces*, P, projecting from the wall at the level of the first and last winders; one of these latter is shown at P, but the other is covered by the fifteenth step.

The trimming joist just below No. 1 step extends of course right across the staircase—but it is in the plan (Fig. 228) supposed to be broken off just under the outer string in order to avoid confusing the plan of the curtail step.

The winders are supported throughout their length by bearers, *bb*, the inner ends of which are built and wedged into the wall of the staircase, the outer ends being tenoned into the circular or wreathed portion of the outer string.

The risers are nailed to these bearers, and the widest ends of the steps are supported by cross bearers dovetailed in between the risers and the longitudinal bearers above mentioned.

The lowest step of this staircase is formed with a curtailed end which, when the tread is on, in form somewhat resembles that shown in the stone staircase, Fig. 208.

In this illustration, however, the tread of the curtail step has been omitted in order to show the construction of the riser below, which is built up in a curved form, terminating in a circular block, which forms the base to support the last baluster or newel.

The inner side of the staircase is finished and embellished by a skirting notched on the under side to fit the steps, and secured to narrow grounds plugged to the wall.

In some cases two cross bearers are provided for each winder, one being framed in between the longitudinal bearers in the centre as well as that at the wide end, as in Fig. 226.

If very thick treads are used, the bearers and rough strings may be omitted altogether, the steps being wedged into the wall and projecting without further support till they reach the outer string.

Fig. 229 is a portion of a stair similar to that in Fig. 227, but with different descriptions of joints between the treads and

risers, enlarged in order to show the plaster and other details,

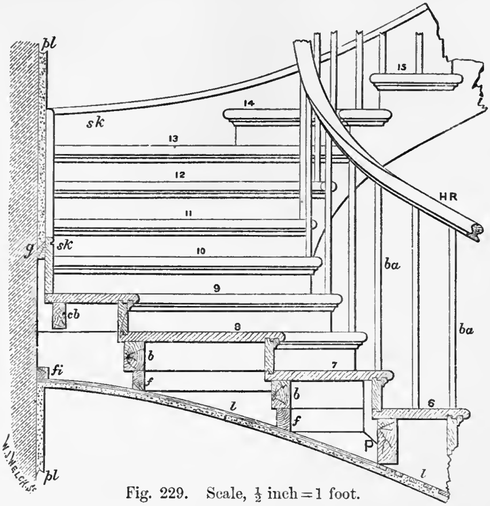


Fig. 229. Scale, ½ inch = 1 foot.

which could not be made clear upon a very small scale.

Solid steps, like those of stone, are sometimes formed in wood for geometrical staircases, and make strong but expensive work.

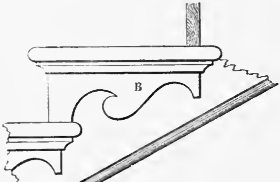


Fig. 230.
Scale, 1 inch = 1 foot.

A Bracketed Stair is one which has ornamental brackets, B, (Fig. 230) fixed on to the end of each step above the outer string and mitred to the outer end of the riser.

They are put on merely for the sake of appearance, and play no part in supporting the steps.

A Curtail Step is one of which the end is projected or curved (as shown in Fig. 205) to receive the newel balusters that support the scroll terminating the handrail.

It is not unusual, especially in stone stairs, to make the last two steps of curtail form, as shown in Fig. 208; in some cases three or more steps are curtailed.

When the end of the step is circular it is called a *round-ended* step.

Carriages is a general name applied to the rough timbers, such as strings, etc., used for supporting a stair.

To avoid framing in bearers for every winding step, two or three carriages are sometimes fixed, as shown in Fig. 233, across the staircase, parallel to the fliers; to these carriages are attached rough brackets for support of the winders, wherever the latter happen to cross them.

HANDRAILING.—The height of the handrail should not be uniform throughout, but varied slightly within the limits of a few inches, so as to secure a graceful line at the changes of inclination.

The handrail should be higher on the landing, where the person using it is erect, than on the steps, where he will be inclining either forward or backward, according as he is ascending or descending the stairs.

[The height from the treads (at the nosings) to the upper surface of the handrail should be 2 feet 7½ inches; to this there should be added at the landings the height of half a riser.—*Newland.*]

For winding stairs regard should be had, in adjusting the height of the rail, to the position of the person using it—who may be thrown farther from it, not only by the narrowness of the treads, but by the oblique position of the risers.

The handrail should be raised over winders, especially those of a steep pitch.

Nicholson recommends that the upper surface of the handrail should have a diameter of $2\frac{1}{4}$ inches; but the sizes vary greatly—3 or $3\frac{1}{2}$ inches by 2 or $2\frac{1}{2}$ deep being common dimensions, while, for very important staircases, the handrail may be 6 × 4 inches, or even larger.

The different sections of handrails are distinguished by peculiar names, according to their shape, such as "Mopstick handrail," a nearly circular form; "Toad's back," which has a flattish, curved upper surface, etc. etc.

The handrail may be secured to the balusters by means of a flat bar of wrought-iron about $\frac{1}{4}$-inch thick, and in width equal to that of the top of the baluster.

This bar, C in Figs. 231, 232, is called a "*core*," and it is screwed down upon the heads of the balusters, and up to the under side of the handrail, as shown in the figure, which represents a piece of the horizontal portion of the handrail to a landing.

Fig. 231.

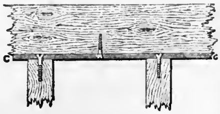


Fig. 232.
Scale, 2 inches = 1 foot.

The balusters supporting the inclined handrail over the steps have their tops splayed to fit the lower surface of the rail. In common work the balusters are nailed to the handrail direct, without the intervention of a core.

A Wreathed Handrail is one which ascends in a continuous curve round a circular well hole, as in Fig. 214.

A Ramp is the sudden rise, concave in form, made by a handrail where it is stopped, as against the newel in Fig. 223.

A Knee is the convex part of the sudden rise in a handrail, as in Fig. 223.

A Swan Neck is a ramp and knee combined, being concave in one part and convex in another; see Fig. 223.

The method of setting out the handrailing for different forms of stairs is quite a science in itself, and is fully treated upon by Mr. Mayer in Newland's *Carpenter's and Joiner's Assistant,* whence many of the above hints have been taken, and to which the student must be referred if he should wish to pursue the subject farther.

BALUSTERS are intended to support the handrail and to prevent any one from falling over the ends of the steps.

They should not be more than about 5 inches apart.

They are sometimes vertical wooden bars, square, turned, or carved, according to the class of work.

An iron baluster of the same pattern as the wooden ones should be introduced at intervals (generally about 1 in every 10) to strengthen the whole.

Iron balusters are frequently used throughout.

Wooden balusters should be dovetailed into the treads of the steps, and secured to the handrail as above described.

The balusters are sometimes fixed to the outer string, being bent or kneed so as to clear the ends of the steps, in order to give as much width as possible to the stairs.[1]

Generally there are two balusters fixed on the end of each step—one flush, or as nearly as possible flush, with the face of the riser, the other midway between the risers.

On each of the narrow ends of winders one baluster only is required.

General Remarks on planning Stairs.—Before planning or laying out a stair, the following particulars are required to be known, and are generally determined by circumstances.

1. The height of the stairs, that is the vertical distance between the surfaces of the floors to be connected by the stair.

[1] This is the French system, and involves the use of iron balusters, or iron balusters and iron brackets, or of iron brackets alone.

2. The position of the first and last risers. These must be conveniently arranged in connection with the approaches, doorways, etc., leading to and from the stairs.

3. The width and length of the staircase available.

4. The position and dimensions of doors, windows, etc., surrounding the staircase, and clear of which the steps must be kept.

These particulars being known, the description of stairs to be adopted can be determined upon, the choice being further influenced by the class of building in which the stairs are to be erected.

Thus, in small common houses or cottages with a very narrow space for the staircase, a straight stair may be necessary. In a slightly better class of house there may be just sufficient width for alternating flights, and a dog-legged stair will be suitable. In buildings on a larger scale, with spacious staircases, a geometrical or open newel stair may be constructed, the well hole increasing in width with that of the staircase.

Circular geometrical stairs with solid or open newels are required in towers, and stairs such as those in Fig. 211 are necessarily made use of in a turret.

The description of stair having been decided upon, no general rule can be laid down for the arrangement of the steps. Some ingenuity and contrivance will be required in order to proportion and arrange them so as to fulfil all the conditions of a good stair fitted to the peculiarities of the position.

Such a stair will consist of flights running alternately in opposite directions, and each containing not more than 10 or 12 steps. All sudden alterations in the length of flights, especially single steps introduced here and there, should be avoided. The landings between the flights should be of a length and width at least equal to the length of the steps. Winders should be avoided as much as possible, and the steps should have the rise and tread carefully proportioned to one another, as directed at page 104. Care must also be taken that when one flight passes under another, or below a landing, there should be plenty of headway; and also that the steps are clear of all doors and windows in the staircase. The stairs should be well lighted throughout their length, more especially at the approaches.

The light may be furnished by windows in the sides of the staircase above the landings, or by a lantern at the top, the latter giving the best and most equally diffused light.

Laying out the plan of Stairs.—Straight Stairs.—The planning of a straight stair is a very simple matter.

The height of the storey being known, a convenient height for the risers, appropriate to the class of staircase (see page 104), is assumed *pro tem.*

The total height to be gained, divided by this dimension, gives the number of risers, the number of treads will be one less (see page 109); and the proper width for each tread (in proportion to the height of the riser) will be found in the table, page 104. If there is room in the staircase for the required number of treads of this width, with the necessary landings, well and good; if not, a steeper rise must be assumed, requiring narrower treads and fewer of them, for which there will be room.

Thus, in the staircase, Figs. 198, 199, the height to be gained is 11 feet 8 inches: assume 7 inches for height of risers, $\frac{140 \text{ inches}}{7 \text{ inches}}$ = number of risers = 20. The width of the tread proportionate to such a riser (see page 104) is 9 inches, the number of treads 19. The total length of staircase required for the treads will be 19×9 inches = 14 feet 3 inches; thus, without a landing, a staircase 14 feet 3 inches long will be sufficient, but with a landing 4 feet wide, substituted for one of the treads (14 feet 3 inches + 4 feet − 9 inches) = 17 feet 6 inches, will be required for the length of the staircase.

The risers must be equal throughout the stairs, none higher or lower than the rest should be introduced to make up an awkward dimension in the vertical distance. Thus, in the case just given, if the height to be gained had been 11 feet 6 inches, the number of 7-inch risers required would have been $\frac{138}{7} = 19\frac{5}{7}$: it would not do to have nineteen 7-inch risers, and one 5-inch riser; but 20 risers would be used, each $\frac{138}{20} = 6\frac{9}{10}$ inches in height, thus equally dividing the vertical distance to be gained.

Laying out Dog-legged Stair.—The number of steps to be introduced is ascertained in the same way as for a straight stair. Thus, in the Fig. 201, a height of 10 feet 10 inches has to be gained, there are 20 risers each $6\frac{1}{2}$ inches high, and the steps have a proportional breadth of 10 inches. The stair is in two flights, each containing 10 steps, and separated by a half-space landing.

The length of staircase required for the width of treads is 9×10 inches = 7 feet 6 inches; and for the landing (equal to width of stairs) 3 feet 6 inches, or 11 feet altogether.

When, however, the area of the staircase is more limited in proportion to the height to be gained, the landing must be made smaller or done away with, and winders introduced; the steps also may be made steeper, so that fewer of them are required, and they take up less room, as the proportionate tread for each is less.

Suppose, for example, that the staircase has a length of only 8 feet, and that the height to be gained between two floors is rather more than before, viz. 11 feet 1 inch (see Fig. 204).

In this case the landing shown in Fig. 200 has to be sacrificed and winders introduced, while the steps are made steeper, so that 19 only are required; the height of each of these is $\frac{133}{19}$ inches = 7 inches,[1] the corresponding tread being 9 inches, the total length taken up by the steps being 6×9 inches $= 4$ feet 6 inches for the fliers—in addition to 3 feet 6 inches (the space containing winders)—altogether 8 feet.

Winders.—In laying out winders it should be remembered that when a person on the stairs is using the handrail he places his foot on the steps about 18 inches in from the balusters; each winder should, therefore, at a distance of 18 inches in from the handrail, have a width equal to that of the treads of the fliers,[2] otherwise (the fliers being properly proportioned) the winders will at this point be too narrow in proportion to their height.

This cannot always be accomplished in dog-legged stairs; for instance, if it were absolutely necessary to introduce three winders into a quarter-space of the landing of the stair shown in Fig. 200, these could only have a width of $9\frac{3}{7}$ inches at 18 inches in from the handrail, whereas the fliers have a width of 10 inches.

For a similar reason *four* winders should be avoided as much as possible in dog-legged stairs. It will be seen in Fig. 226 that the width of treads at 18 inches from the newel can never be more than 7 inches. Thus the treads of the winders must be narrower than those of the fliers, and therefore inconvenient.

Four winders are, however, very frequently introduced as shown, for they are often absolutely necessary in order to gain the height required within the space available.

[1] If the height to be gained were the same as in Fig. 201, viz. 10 feet 10 inches, the rise for the steps would be $\frac{130}{19} = 6\frac{16}{19}$ inches.

[2] If the staircase be narrower than 3 feet, the width of treads should, of course, be laid off along the centre of the winders. It is sometimes considered better to have three or even five winders than four; because when there are four there is a riser of needless length running into the angle of the staircase (see Fig. 226).

As it is difficult to follow these rules under all circumstances, they are often infringed, and in common staircases it is considered quite sufficient if there is a proper width of tread in the centre of the length of the winders.

"Balanced" or "Dancing" Steps.—In consequence of the inner ends of winders having such narrow treads, while their height is the same as that of the other steps, the inclination of the line of nosings of the winders is much steeper than that of the fliers—which gives a sudden and ungraceful change to the inclination of the handrail above them.

To avoid this, and in order to gain some additional width at the inner ends of the winders, they are in some cases made to "dance,"—that is, they are drawn so as not to converge to the same point, but so that each is directed upon a different point—found in a manner too intricate to be entered upon in this Course.

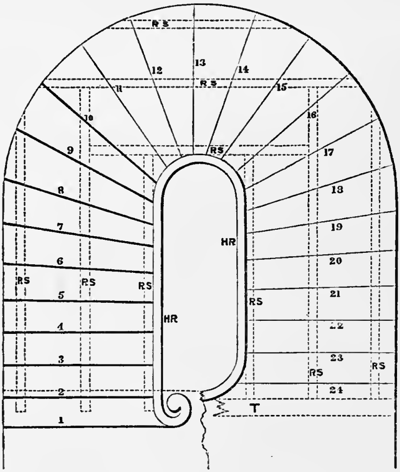


Fig. 233. Scale, ¼ inch = 1 foot.

In Fig. 233 the first four and the last four steps are parallel—but the remainder are "balanced" or "dance," as above described.

Geometrical Stairs.—In laying out geometrical stairs the steps are arranged on the same principles as those above described.

The well hole in the centre is first laid down and the steps arranged round it.

In circular stairs with an open well hole, as in Fig. 213, the handrail being on the inside, the width of tread proportioned to the rise of steps should be set off along the dotted line, 18 inches in from the handrail, for the reasons above mentioned.

In stairs with a newel, such as that in Fig. 209, when the handrail, if any, might be on the outside, it will be sufficient if the steps have the proper width of tread in the centre of their length.

When laying out stairs practically on the building itself, the height to be gained is carefully marked out upon a "*story rod*," on which are marked divisions corresponding in number and height to the risers: a similar rod is marked so as to show the treads; and from these rods the steps should be carefully marked upon the walls of the staircase.

A rod should also be prepared having marked upon it the exact width of the staircase, the length of steps, the position and size of newels, and also the size of the wall and outer strings, showing the thickness and the depth of the housings.

CHAPTER VI.

FIREPROOF FLOORS.

General Remarks.—Fireproof floors are of great service in preventing flames from spreading throughout a building.

A great many different systems of fireproof construction have been proposed during the last few years; and before describing the most important of these it will be desirable to state what characteristics should be looked for in a good fireproof floor.

Characteristics of good Fireproof Floors.

In estimating the efficiency of any system of fireproof flooring the undermentioned points should be attended to.

A, PROTECTION OF IRONWORK.

The structure of a fireproof floor is generally dependent upon the ironwork; if that is destroyed or gives way the floor must follow. Iron girders and columns may be protected by terra-cotta blocks, see Figs. 236, 255, etc, or by concrete, see Figs. 251, etc.

B, RESISTANCE TO FIRE OF THE MATERIAL COMPOSING THE FLOOR.

Brickwork and hard burnt clay are the best fire-resisting materials.

Wrought-iron, if not protected by a non-conductor of heat, will warp and twist under the action of fire and destroy the structure.

Cast-iron cracks and gives way suddenly, especially when it is heated and then drenched, as it is likely to be during a fire. In the Chicago fire the ends of cast-iron columns were actually melted off.

Timber in large scantlings will resist the action of fire for a long time if the flames cannot get round its sides or ends. After it becomes charred to a certain depth the charcoal formed on its surface, being a non-conductor, protects it.[1]

[1] Lawford, *Transactions*, Society of Engineers, 1889, p. 43.

Wooden floors will resist a considerable action of fire if well imbedded in mortar, which, however, leads to their premature decay.

Wood may be rendered partially fireproof by being coated with cyanite, Asbestos paints, or other substances mentioned in Part III.

Concrete is generally a good fire-resisting substance, but this depends to some extent upon the materials of which it is composed.

Gypsum (sulphate of lime) is weaker than Portland cement, but resists fire better, as it does not lose its cohesive power even when raised to a white heat and then drenched with water.

Broken brick or stone, for the aggregate, stand fire better than breeze, which will burn away under very high temperatures.[1]

Slag cement is likely to be largely used for concrete floors in this country. It is cheaper and lighter than Portland cement, while its fire-resisting properties exceed those of Portland cement or gypsum.[2]

Plaster also resists fire well, especially when it is nearly entirely made with gypsum, as in the Hitchins Company's and Robinson's plasters.

Stone is a very bad material for fireproof structures ; when subjected to great heat it suddenly cracks and gives way without warning. For this reason arches of fireproof construction should never rest upon projecting stone corbels.

In the Chicago fire, sandstone was found to stand better than limestone. Granite was quite disintegrated, or, under less heat, scaled.[2]

Silicate cotton, slag wool, and similar materials are fireproof, and very useful for pugging floors or partitions.

c, Cost.—Under this head must be considered not only the cost of the floor itself but the expense it leads to.

Thus a deep floor will involve extra height of walling, and an arched floor, having a thrust upon the walls, will necessitate their being of extra thickness.

d, Strength.—The floor must of course be strong enough to bear the weights it may be required to carry.

This can easily be arranged for, as it is a mere question of the thickness of arches and dimensions of the girders, and other parts of the floor.

e, Permanency.—Floors of materials subject to decay from dry rot and other causes must of course be carefully avoided.

Recapitulating, we see that a good fireproof floor should be of good fire-resisting material—all ironwork being protected by non-conductors—that it should not lead to expense in other parts of the building, should be strong enough to carry the weights required to be placed upon it, and not liable to decay.

[1] Lawford, *Transactions*, Society of Engineers, 1888.
[2] Gass, *Transactions*, R.I.B.A., 1886, p. 134.

The student should test each floor described by seeing which it possesses of the characteristics described above. In selecting a floor for any particular purpose some of these characteristics will be more important for that purpose than others, and it is impossible to say abstractly that any system is the best under all circumstances.

DIFFERENT FORMS OF FIREPROOF FLOORING.

A great many different forms of fireproof flooring have been proposed and made use of during the last few years.

They may be generally classed under four heads.

A. Arches of brick or concrete supported upon walls or girders.

B. Hollow bricks or tubes supported between girders and filled in with concrete.

C. Concrete filled in between and around girders.

D. Solid timber of considerable thickness.

E. Iron plates resting on girders.

Arched Systems.

Girders and Brick Arches.—Among the earliest forms of fireproof floors were those consisting of brick arches of small or moderate span, supported by cast- or wrought-iron girders.

Such constructions are still in use for mills, warehouses, sugar factories, and other buildings, where great weights have to be stored.

Fig. 234 is a transverse section of part of a floor composed of brick arches resting upon cast-iron T girders, G G. Wrought-iron rolled joists would of course be far better.

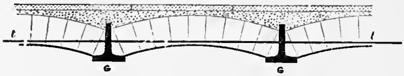


Fig. 234.

The girders may be placed from 4 to 12 feet apart; the arches turned from one to the other; the spandrils filled in and levelled up with concrete, and covered with a floor of any material.

A tension rod, *t t*, unites the girders, and prevents their yielding under the thrust of the arches. The nearer the tension rod is to the springing of the arch the better, but it is frequently kept high up within the arch in order that it may not be visible.

The tension rod is often used only for the outer arches of a series; these, being thus prevented from yielding, form an abutment for the others.

In arches of a larger span the thickness of the brickwork may be increased toward the haunches, as shown in Fig. 235.

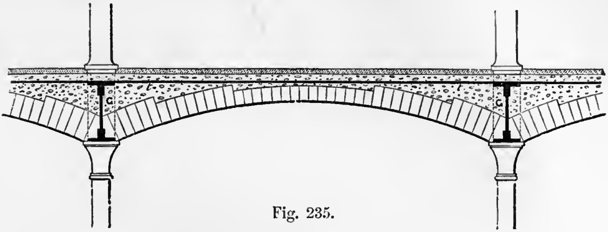


Fig. 235.

This increase of thickness is useless unless the extra rings are bonded in with the others, or built with bricks the full depth of the arch, which amounts to the same thing.

Sir W. Fairbairn recommends that the rise of such arches should be $\frac{1}{10}$ the span for floors of mills, and $\frac{1}{8}$ the span for warehouse floors to carry heavy weights.

Fig. 235 shows an arch of about 10 feet span, carried by wrought-iron plate girders, with angle iron flanges. These girders run at right angles to the arches, their ends rest upon the heads of columns, and the girders are laterally tied together by flat iron bars, *t t*, secured to their upper flanges.

Whichcord's Fireproof Blocks.[1]—It will be seen that in the systems above described the lower surfaces of the iron girders are exposed to the direct action of fire.

To prevent this, the late Mr. Whichcord imbedded them in fireclay blocks, which protect them from fire, and, at the same time, form skewbacks for the arches.

Fig. 236 shows in section a rolled girder with protecting fire blocks, BB. These are made in lengths of 9 inches, and with a minimum thickness at any point of $1\frac{1}{2}$ inch of fireclay, which has been found to resist the greatest heat to which such a structure is likely to be subjected.

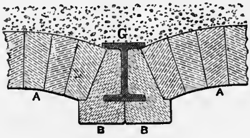


Fig. 236.

Where ceiling joists are used, they may be supported on the lower ledges of the fire blocks.

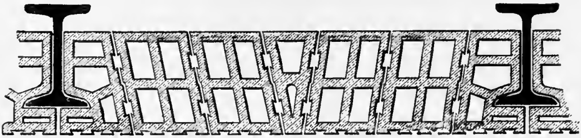
Doulton-Peto System, Fig. 237.—In this the blocks or voussoirs of the arch are of hollow fireclay blocks, which are stated

[1] Used at the National Safe Deposit Co.'s Warehouse.

to be $\frac{1}{3}$ lighter than bricks or concrete. The under sides of these are dovetail grooved so as to form a key for the plastering.

This flooring is capable of sustaining great weights; the girders are well protected; the arches being light may be of considerable span, though large spans increase the depth and cost of the floor, and, moreover, they do exert a certain amount of thrust upon the walls.

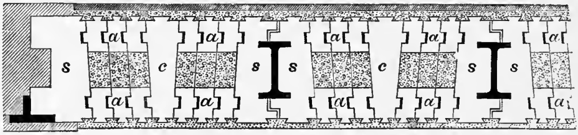
This flooring has been used at Whiteleys, The London Pavilion, National Provincial Bank, and in several warehouses.



DOULTON-PETO'S SYSTEM.
Section of 8-inch Flooring.
Fig. 237.

NORTHCROFT'S SYSTEM[1] consists of flat arches of specially moulded fire-bricks, resting upon fire-brick skewbacks supported by I iron girders.

These girders rest at the ends upon turned rollers, and are thus permitted to expand when heated.



NORTHCROFT'S SYSTEM.
Fig. 238.

In Fig. 238, *a a a* are the flat arches 6 inches deep, with a filling between of 6 inches of concrete. S S are the skewbacks, which are bedded in asphalte upon the I girders. The soffit is plastered to form a ceiling, and the surfaces of the floor finished off with parquet, cement, asphalte, or in any way that may be desired.

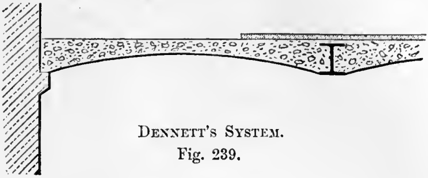
DENNETT'S FIREPROOF FLOOR consists of concrete arches supported where they abut upon the walls by projecting courses, and at intermediate points by rolled or riveted iron girders, as shown in Fig. 239.

The arches should have a minimum rise of 1 inch to every foot of width up to spans of 10 or 12 feet, and are sustained by centering until they are thoroughly set.

The concrete used has sulphate of lime (gypsum) for its

[1] From *Our Factories, Workshops, and Warehouses*, by R. H. Thwaite, C.E.

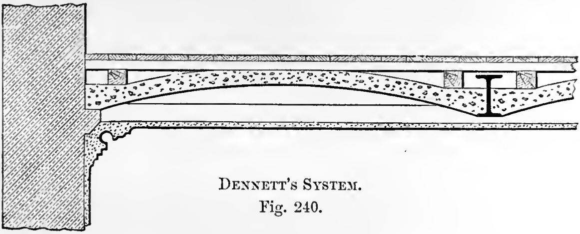
matrix. It has been proved that this substance does not lose its



DENNETT'S SYSTEM.
Fig. 239.

cohesive power even when it is raised to a white heat and then drenched with cold water.

The floor above the arch may be formed by simply bringing



DENNETT'S SYSTEM.
Fig. 240.

the concrete itself to a smooth surface. Joists may be nailed to fillets laid upon the concrete, in a similar manner to that shown in Fig. 240, or the surface may be paved as in Fig. 239.

The soffit of the arch may be finished at once with the setting coat of plastering;[1] or, if a flat ceiling is necessary, joists must be fixed to the lower flanges of the girders to carry the lath and plaster. The laths are not shown in Fig. 240.

Figs. 239, 240 are taken from Messrs. Dennett's pamphlet.

WILKINSON'S SYSTEM is very like Dennett's in form, but the arches are of concrete granite and the ceilings formed with fibrous plaster slabs.

This system has been used at Edinburgh University, several stations on North-Eastern Railway, by the War Department, and in many warehouses.[2]

LINDSAY'S ARCH SYSTEM consists of "Pumice concrete"[3] arches resting upon girders which are stiffened by truss rods, and whose

[1] Concrete arches are often laid upon a soffit of corrugated iron, which supports the concrete while it is being laid and protects it afterwards.
[2] Lawford, *Transactions*, Society of Engineers, 1889. [3] See p. 144.

lower flange is protected from fire by an iron trough filled in with pumice concrete.

WOOD AND CONCRETE FLOOR.—Fig. 241 gives the section of a floor that was used for the office of the Board of Works in London, and which will resist fire to a considerable extent.

Fig. 241.

Fig. 242.

The joists are cut diagonally of triangular section, see Fig. 242, and are placed about 18 inches apart, so as to form skew-backs to concrete arches filled in between them.

BUNNETT'S SYSTEM[1] consists of hollow bricks of a peculiar shape laid in a flat arch from wall to wall, resting on angle irons held together by a tension rod passing through the bricks. The bricks are so arranged and formed laterally that each receives the support of six adjoining bricks. The under sides of the bricks are dovetail grooved to afford a key for the plastering.

TILE FLOORS consist of arches formed with flat tiles resting upon girders, in the same way as the brick arches above described. When the centering is fixed, the first course of tiles is laid dry, and then covered with cement; upon this a second, third, and fourth course are laid in the same manner. The spandrils are filled in with concrete, and the floor finished with joists and boarding, pavement, or in any way that may be desired.

Disadvantages of Arched Floors.—Arched floors, especially when composed of voussoir blocks, are complicated and heavy. The arches depend greatly upon one another, and if one gives way it may lead to the failure of the whole floor. In any case they exert a thrust upon the walls.

These disadvantages have led to the adoption of simpler forms of fireproof flooring.

Systems with Hollow Bricks or Tubes.

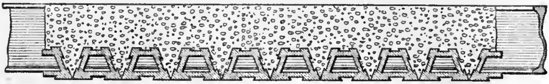
In order to avoid the lateral thrust of arches upon the walls, various systems have been proposed in which hollow bricks or

[1] Used at Grosvenor Hotel.

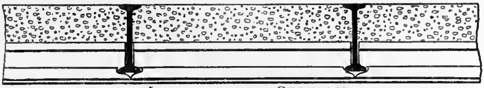
tubes are suspended by means of T or L irons between I joists, and the spaces between and above them filled in with concrete.

Systems with Hollow Bricks or Tubes.

HOMAN AND RODGERS' SYSTEM (Figs. 243, 244) consists of pur-



CROSS SECTION
Fig. 243.



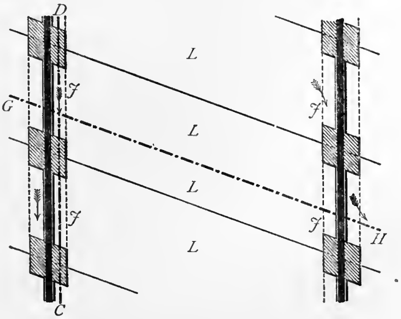
LONGITUDINAL SECTION
Fig. 244.

pose-made hard burnt bricks with moulded projections, protecting the iron joists upon which they rest, and filled in with concrete.

As the concrete is tough the boarding of the floor may be nailed to it direct, but inch-sleeper fillets are recommended so as to leave a space for ventilation, gas and water pipes, etc.

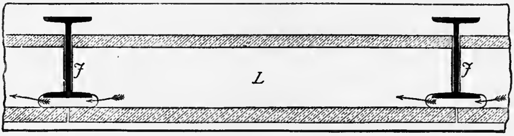
The soffits of the hollow bricks are dovetail grooved as a key for the plaster ceiling, and the depth of the finished floor is only 6 to 9 inches.

Fig. 244 is a longitudinal section, and Fig. 243 a cross section, of the floor.



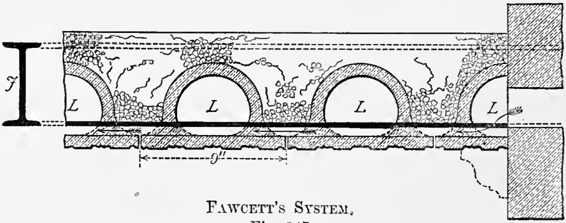
FAWCETT'S SYSTEM.
Fig. 245.
Plan of ironwork and tubular lintels fixed ready for concreting.

Fawcett's system (Figs. 245 to 247) *consists of Fireclay* or red clay tubes, or, as they are called by the inventor, "lintels," of the section shown at *L*, Fig. 247, which rest upon the lower flanges of wrought-



FAWCETT'S SYSTEM.
Fig. 246.
Longitudinal section G, H, showing the tubular lintel encasing the joist, and the admission of cold air into the end of the tubular lintel.

iron rolled I joists 2 feet apart. The lintels are placed obliquely between the joists—their own diagonals being at right angles to the joists. The spaces between and above them are then filled in with concrete—their lower sides are grooved as a key for plastering.

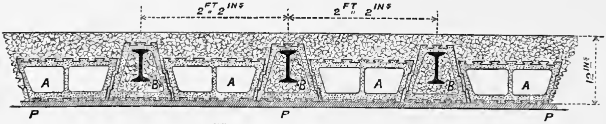


FAWCETT'S SYSTEM.
Fig. 247.
Transverse section C, D, showing the air passage under the joists and the admission of cold air into the side of the lintel.

The weight of the floor is taken by the joists and concrete, the lintels acting merely as a permanent centering and casing to the ironwork, which is well protected.

This system has been used for a warehouse in Southwark.

HORNBLOWER'S SYSTEM.—One form of this system is given in Fig. 238,



HORNBLOWER'S SYSTEM.
Fig. 248.

which shows the construction recommended by Mr. Hornblower for a floor to carry as much as two tons per superficial yard over a bearing of 18 feet.

A A are large hollow fireclay tubes; B B are smaller tubes of the same

material, containing iron I girders as shown, and filled with fine Portland cement concrete, gauged 4 to 1 ; concrete is also packed in between and over the tubes ; P P is the plaster ceiling below, the key for which is afforded by indentations or grooves formed on the lower side of the tubes.

Girders filled in with Concrete.

In these systems there is no thrust upon the walls, and they are efficient if the ironwork is well covered by non-conducting material.

Fox and Barrett's Floors consist of wrought-iron girders placed about 20 inches apart, at right angles to which, and resting on their bottom flanges, are laid rough fillets or strips of wood 1 inch or $1\frac{1}{4}$ inch square, and about $\frac{1}{2}$ inch apart. Concrete is

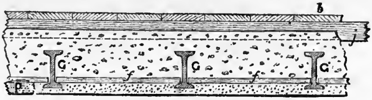
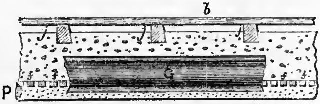


Fig. 249. Cross section.



Fox and Barrett's System.
Fig. 250. Longitudinal section.

then filled in between the joists—being supported by the fillets —which form a key to the plastering of the ceiling below.

In order to avoid all inflammable material, small earthenware drain pipes have been used instead of wooden fillets.

Fig. 249 shows a transverse section, and Fig. 250 a longitudinal section, of such a floor.

G G are the wrought-iron girders, *f f* the fillets, P the plaster of the ceiling below.

The surface of the floor in the example shown is covered with boards laid upon the joists, *j j*, which are embedded half their depth in the concrete, and cut to a dovetail section to keep them firm.

Sometimes the concrete is filled in only up to the upper surface of the girders, and floor joists or paving laid upon it.

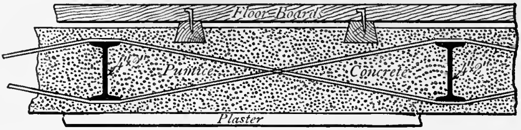
The concrete used for fireproof flooring of this kind should be of a quick-setting lime or cement, for until it has set its full weight comes upon the girders, but when it is solid it forms a series of flat arches between the girders and strengthens the floor.

If the concrete is thick, it should be applied in two layers to hasten its drying.

Care must be taken that the floor has a good abutment on each side, or is well tied together.

When the lower flanges of the girders are so wide that they would interrupt the key of the plaster and prevent its adherence, light ceiling joists are sometimes secured to the under side of the fillets at right angles to them. These are lathed and plastered in the usual way.

LINDSAY'S SYSTEMS.—*a, With* I *Girders.* The first of these (Fig. 251) consists of wrought-iron or steel I joists, spaced from 18 inches to 3 feet apart, and trussed by pairs of rods about 18 inches



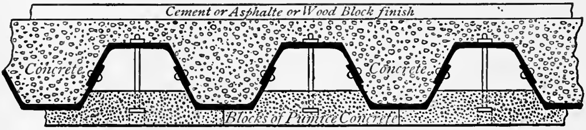
LINDSAY'S SYSTEM WITH I GIRDERS.

Fig. 251. Cross section for boarded floor with embedded sleepers.

apart, as shown in Fig. 251, which clip on to the lower flanges of the girders. Concrete made of coke breeze, mineral sand, and Portland cement—known as "pumice concrete"—is filled in and around the girders and rods. Among the advantages claimed for this floor are the composition of the concrete, which makes it 25 per cent lighter than ordinary concrete, also that if parts of the concrete are damaged the remainder is kept in position by the truss rods.

This system has been used for the Branch Bank of England, Royal Infirmary (Liverpool).

LINDSAY'S SYSTEMS.—*b, With Trough Girders* (Fig. 252). In this system wrought-iron or steel girders of trough section riveted



LINDSAY'S SYSTEM WITH TROUGH GIRDERS.

Fig. 252. Section of floor with concrete blocks under.

together are filled in with "pumice" concrete. When there is no substantial ceiling the lower surface of the ironwork is open to the action of fire, but this may be avoided by fixing pumice concrete blocks or slabs below instead of an ordinary plaster ceiling.

This system has been used at the National Liberal Club,

Prudential Assurance Company (Brook Street), Messrs. Maples, Dublin Museum, and by several Railway Companies.[1]

Strained Wire System.—In this, $\frac{1}{4}$ or $\frac{3}{8}$-inch rods, about 18 inches apart, are strained through holes in the webs of the joists, and fixed to the walls. A network is thus formed, and concrete is filled in around and below the joists so as to protect them. This system is also used for roofs.

Slabs of Pumice Concrete laid upon the lower flanges of joists, and formed with a projecting piece below to protect those flanges, make a fireproof floor which is quickly carried out.

For *Lindsay's Arch System*, see p. 139.

PIERSON'S SYSTEM, formerly *Gardner, Anderson, and Co.'s.,* is practically the same as Lindsay's I girder system with the truss rods omitted.

MORELAND'S SYSTEM is practically the same as Lindsay's trough system, but that the section of the troughs is rectangular instead of splayed.

DAWNAY'S SYSTEM consists either of $\frac{1}{2}$-inch square iron bars 12 inches apart, or of small 3-inch joists 16 inches apart, resting on the lower flanges of 5-inch binding joists in 7-inch bays; concrete of broken brick and Portland cement is filled in between and around the joists. This construction is suitable for spans up to 30 feet, the binding joists being strengthened according to the increase of span.

This system has been used at the Charing Cross Hotel, Colonial Institute, Exeter Hall, several Board Schools, and other buildings in London.

ALLEN'S SYSTEM consists of Portland cement concrete strengthened by iron bars. Bars about 3 inches by 1 inch are placed on edge across the building, 2 feet apart, and built into the walls on either side; across these are placed $\frac{1}{2}$-inch iron rods, also 2 feet apart, thus forming a network with meshes 2 feet square. A temporary scaffold is formed underneath the network, and the concrete—composed of 1 Portland cement to 4 of clinkers, slag, etc.—is thrown in to a depth of 4 inches; when it is set the scaffolding is removed.

Solid Timber Floors.

EVANS' AND SWAIN'S SYSTEM (Fig. 253) consists of timber joists spiked close together without any spaces between. The

[1] Cunnington, *Building News,* 15th March 1889.

depth of the joists varies from $4\frac{1}{2}$ inches for 8 feet spans to 11 inches for 30 feet spans. The spikes are about 18 inches apart, holes being bored for them to prevent splitting.

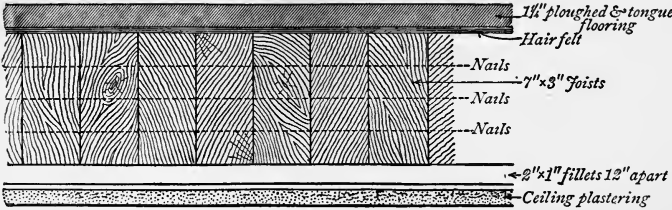


Fig. 253.

All cracks or shrinkages in the upper surface of the floor are filled up with a grouting of liquid plaster, while the plaster ceiling may be attached, as shown, to the under surface of the joists, alternate joists being less deep, so as to form a key, or it may be attached to laths upon fillets.

The advantages of this floor are, that it is simple, and composed entirely of timber in large scantlings and plaster, both of which offer a very considerable resistance to fire.

Girders with Plates.

Girders with Cast-Iron Plates.—Fig. 254 is the sectional elevation of a floor formed as follows :—

Wrought-iron rolled or built-up girders, G, span the room at from 10 to 15 feet central intervals.

Running at right angles to these, and resting upon them, are rolled joists, J J, about three feet apart. Upon the upper flanges of these joists are laid cast-iron plates shown in section at C, the joints being so shaped as to over-

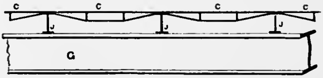


Fig. 254.

lap one another. The under side of these plates may be cast to a pattern, so as to form an ornamental ceiling.

Another row of cast-iron plates may, if required, be placed on the lower flanges of J J. The space between the two sets of plates may be left hollow so as to contain a stratum of air for coolness, or it may be filled with deafening composition, slag wool, or concrete.

The cast-iron plates are, of course, an objection to this system.

Girders with Wrought-Iron Plates.—Some years ago Sir W. Fairbairn recommended fireproof floors constructed with wrought-iron plates of arched form riveted to the lower flanges of the girders, and filled up to the level of the

floor with concrete, thus forming concrete arches of some 10 or 12 feet span with a wrought-iron lining to the soffit, supported at intervals by T iron ribs.

For smaller spans Mallet's buckled plates (see Part III.) have been used, their edges being riveted to the lower flanges of the girders upon which they are laid.

Weight and Cost of Different Systems of Fireproof Flooring.

The following Table is slightly modified from one given by Mr. Lawford in a paper read before the Society of Engineers.[1]

Approximate cost, weight, and safe load of each floor undermentioned—for 12 feet bearing.

Constructers.	Cost per Square Yard.		Weight per Square Foot.		Safe Load per Square Foot.
	Excluding Joists.	Including Joists.	Excluding Joists.	Including Joists.	
Arched.	*s. d.*	*s. d.*	lbs.	lbs.	cwt.
Dennett . . .	6 9	9 3	50	54	2
Doulton . . .	6 6	9 0	30	34	2
Wilkinson . . .	6 0	7 6	50	52	2
Flat.					
Dawnay . . .		7 0		40	2
Gardner . . .		7 0		46	2
Homan and Rodgers		7 0		35	2
Lindsay, *a* . .		7 0		44	2
Evans and Swain .	10 6	No joists required.	20	No joists required.	7

American Systems.[2]

ARCHED FLOORS are much used in America—either brick arches supported by iron girders with "porous terra cotta,"[3] protecting blocks forming skewbacks, or arches of hollow blocks like those in the Doulton-Peto system (Fig. 237), or concrete arches like those of Dennett, but supported upon corrugated iron soffits.

PUGGED FLOORS.—A section of one of these is shown in Fig. 255. It consists of wooden joists on which 2″ × 1″ strips support a course of bricks whose upper surface is covered with a layer of concrete, and upon which is a tiled or boarded floor. The ceiling is of terra-cotta tiles fixed to the joists by iron clips—jointed, and plastered below.

Slow-burning construction[4] is a term applied to the kind of floor generally used for mills and warehouses. These consist of solid beams or beams bolted together and 8 or 10 feet between centres,

[1] *Transactions*, Society of Engineers, 1888, p. 58.

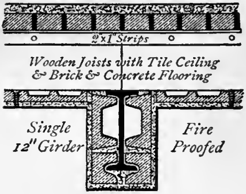
[2] *Transactions*, R.I.B.A., 1886, p. 129, Mr. Gass's paper.

[3] Porous terra cotta is composed of clay mixed with combustible material, such as sawdust, cut straw, charcoal, etc. When baked the combustible material is consumed, leaving the terra cotta full of holes. It is fireproof, light, will hold nails, and gives a good surface for plastering (see Part III.)

[4] Woodley's *Fire Protection of Mills*, New York.

upon these are laid floor planks 3 inches to $3\frac{1}{2}$ inches thick, over which is spread a layer of mortar $\frac{3}{4}$ inch thick, and over this again is laid a grooved and tongued floor of hard wood $1\frac{1}{4}$ inch thick. Sometimes two thicknesses of rosin-sized sheathing paper are substituted for the layer of mortar.

Fig. 255.



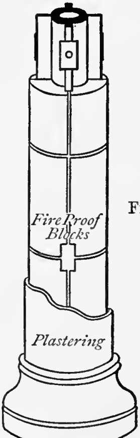


Fig. 256.

Fig. 257.

General.—Ironwork is always protected by terra-cotta blocks (Figs. 255-257[1]), plaster, etc. Ceilings are of terra-cotta tiles, or plastered on wire-cloth netting with $\frac{3}{8}$ inch squares. Exposed woodwork is protected by terra cotta or sheets of tin. Partitions are of hollow tiles.

Fireproof Roofing is not much in fashion in this country, though Lindsay's strained wire system has been used for part of the roof of the National Liberal Club, Branch Bank of England,[2] etc. In America it is sometimes constructed with porous terra-cotta blocks resting on T irons supported by I beams, or roof trusses are encased in terra cotta.

French Systems.—Wrought-iron girders were adopted for fireproof floors in Paris some time before they were known in England, and any notice of the different systems of fireproof flooring, however brief, would be incomplete without a reference to some of the plans originated in France.

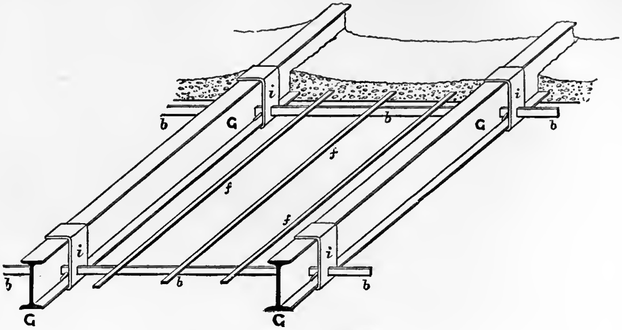
Though these are not commonly adopted in this country, some description of them may be useful in suggesting ideas for new systems, which may be arranged and modified in accordance with more recent experience.

Thuasne's System consists of I-shaped wrought-iron girders slightly arched, with a rise of about $\frac{1}{200}$, and placed at about 3 feet 3 inches central intervals. At right angles to them, and also 3 feet 3 inches apart, are laid flat iron bars or *interties*, *b b b*, whose ends pass through slits in wrought-iron bands, *i i i*, which embrace the girder at intervals of 3 feet 3 inches. The ends of the interties are secured by a pin passing through them on the farther side of the iron band.

[1] From *Transactions*, R.I.B.A., 1886, Pl. XVIII.
[2] Cunnington, *Building News*, 15th March 1889.

Crossing the interties at right angles are light iron rods called "fautons," *f f f*; these are generally about $\frac{1}{2}$ inch square (not flat as shown in Fig. 256), placed about 9 inches apart, and bound to the interties with wire.

A flat centering or boarding is placed under this network, and coarse plaster of Paris is poured in upon it to a thickness of about 3 inches. This



THUASNE'S SYSTEM.

Fig. 258.

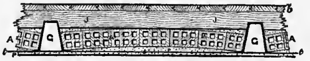
soon becomes hard, and serves not only to stiffen the floor but to form the ceiling, a fine coat being required on the under side as a finish to superior work.

The girders are tied into the walls at each end by iron straps secured to vertical bolts in the wall.

Small square wooden joists are laid over the girders, and boarded in the usual way.

In some cases cast-iron chairs are used instead of the wrought-iron straps to carry the ends of the interties.

FER TUBULAIRE is the French name for a girder of peculiar form invented by M. Zorés and shown in Fig. 259.



FER TUBULAIRE.

Cross Section. Fig. 259.

Longitudinal Sectional Elevation. Fig. 259*a*.

Floors of this kind were exhibited in the Paris Exhibition of 1857, and have been used for warehouses in this country.

They are thus described in the official report on civil construction.

"The 'fer tubulaire' may be described as being in section of the form of a capital A without the small triangular top. Those exhibited are said to be for a bearing of 20 feet, and are of the following dimensions—viz. $4\frac{3}{4}$ inches high, $2\frac{3}{8}$ inches wide at top, 4 inches wide at bottom exclusive of a small flange of $\frac{3}{4}$-inch projection on each side. The sides of the girder are $\frac{3}{10}$ths of an inch in thickness, and the top and flanges $\frac{7}{20}$ths. These girders are placed at a distance apart of 2 feet 8 inches from centre to centre, and are tied together at intervals of three feet by flat bar-iron ties of $\frac{3}{4}$ inch by $\frac{3}{10}$ inch bolted to the bottom of the flanges, and the flooring finished according to one of the following methods:

"Method No. 1.—Flat arches of hollow brick between the girders, with joists of 'fer à coulisse' (hereafter described) or of wood and wooden flooring, or for passages with the spandril filled in with plaster, and floored over with tiles ceiled underneath to soffit of flat arch.

"Method No. 2.—The spaces between the girders filled in with hollow blocks of plaster 4 inches deep. Flooring and ceiling as in No. 1.

"Method No. 3.—Wooden flooring as in No. 1, with ceiling on small iron laths hollow between floor and ceiling.

"Method No. 4.—Wooden flooring without ceiling."

The girders of this ∩ section (G G in Fig. 259) are said to possess the following advantages over those of the I form, commonly used:

"First, With equal weights they give a strength or resistance nearly double.

"Second, A floor constructed with these girders costs some 20 per cent less than one similar in all respects but constructed with girders of I section.

"Third, This form of joists requires no strutting, while the I girder requires lateral pressure to such an extent that it is said not to be employed to the best advantage unless absolutely filled in with either hollow brick arches or plaster, more than half its strength being dependent upon its lateral rigidity."

Fer à Coulisse.—This is a form of iron joist resembling the I section, but with three flanges, the second longer than the upper flange and close below it.

Fig. 260 shows at *f* this form of girder in use as a common joist.

The main girders of fireproof floors have also been made in France of this section.

The girders are placed about 20 inches from centre to centre, and the space between them filled in with hollow bricks, or a hollow block of plaster resting on the lower flanges. The advantages claimed for these girders are, that the second flange assists the top flange in affording the necessary resistance to compression when the girder is loaded, and that it also stiffens the girder in a lateral direction; and further, that it affords a convenient arrangement for laying the boarding at once without the intervention of joists, and without employing nails.

Fireproofing existing wooden floors.

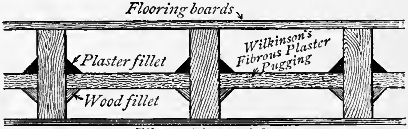


Fig. 260.

Messrs. Wilkinson have a system shown in section Fig. 260 by which existing wooden floors can be converted into "slow-burning constructions."

The ceiling and the pugging of the floor are formed of non-inflammable fibrous plaster slabs, $\frac{7}{8}$ inch thick, the latter laid in the usual way upon wood fillets fastened to the joists and secured by plaster fillets above.

The fibrous plaster slabs are made of coke breeze and plaster on a basis of cocoa-nut fibre. They make a very light floor which does not require such thick supporting walls as do floors of concrete (see also fireproof plastering, p. 135).

The systems of fireproof flooring that have been introduced or proposed at different times are almost innumerable. The shape of the girders has been varied in every possible way, and all sorts of materials used in connection with them.

Several new forms have been proposed during the last few years, but many of them have not been fully tried. The subject is one of great importance, and will no doubt be greatly developed.

Encasement of Girders and Columns in Concrete.

As above stated, it is necessary that all iron work should be protected from the fire by some non-conducting substance. Figs. 261, 261*a* show the method adopted by Messrs. Dennet and Ingle for encasing both columns and girders in concrete.

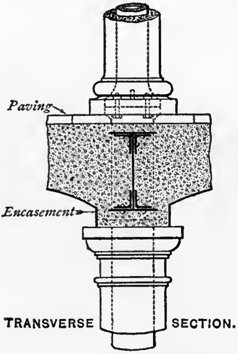


Fig. 261.

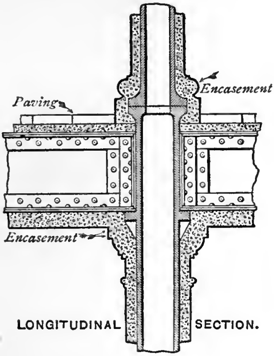


Fig. 261*a*.

Chapter VII.

IRON ROOFS.

THIS Course includes roofs of from 40 to 60 feet span.

Such roofs come under the first head of the classification given in Part I., as they can easily be formed with straight rafters, and it will therefore be unnecessary to notice roofs with arched rafters or mixed roofs in these Notes.

Plate IV. shows various forms of trusses for iron roofs of spans up to 60 feet. As it has already been described in Part I. nothing need be said about it here. It will be noticed that the trusses are so arranged that the principal rafters are supported at intervals not greater than 8 feet.

Trussed Rafter Roofs.—In Part I. illustrations and descriptions were given of a roof in which each principal rafter was trussed by means of a strut supporting it in the centre (Figs. 264, 265), the strut itself being sustained by tension rods connecting it with the ends of the rafter.

Such an arrangement is best adapted for roofs up to 30 or 40 feet span; but when, as in larger roofs, the rafters become very long, they require support at more than one central point.

Truss with two Struts.—Figs. 266, 267, 268, Plate IV., show various forms in which a truss with two struts to support the principal rafter may be constructed. Details of such trusses are given in Plates IV. V. VI. Part I., also in Plates VII. VIII. of this Part.

Truss with three Struts.—In roofs of more than 40 feet span the rafters become so long as to require support at three intermediate points; the same principle of trussing may be continued as shown in Fig. 281 and in Plate IX.

Fig. 281 on page 155 is also an example of a trussed rafter roof with 3 struts. In this example the rafters are of T iron, the struts of double T iron riveted back to back. The tie rod and upper tension rod are of round iron, and the lower tension rod is of double flat bar iron.

The covering is of slates laid on boarding supported by angle iron purlins filled in with wood.

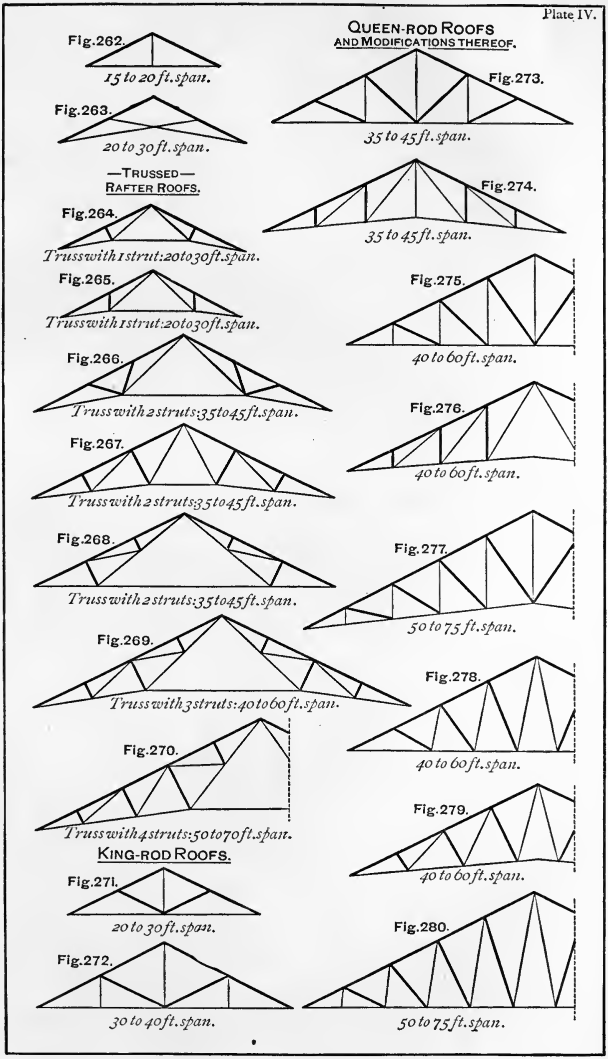


Plate IV.
Fig. 262.
15 to 20 ft. span.
Fig. 263.
20 to 30 ft. span.
—TRUSSED—
RAFTER ROOFS.
Fig. 264.
Truss with 1 strut: 20 to 30 ft. span.
Fig. 265.
Truss with 1 strut: 20 to 30 ft. span.
Fig. 266.
Truss with 2 struts: 35 to 45 ft. span.
Fig. 267.
Truss with 2 struts: 35 to 45 ft. span.
Fig. 268.
Truss with 2 struts: 35 to 45 ft. span.
Fig. 269.
Truss with 3 struts: 40 to 60 ft. span.
Fig. 270.
Truss with 4 struts: 50 to 70 ft. span.
KING-ROD ROOFS.
Fig. 271.
20 to 30 ft. span.
Fig. 272.
30 to 40 ft. span.
QUEEN-ROD ROOFS
AND MODIFICATIONS THEREOF.
Fig. 273.
35 to 45 ft. span.
Fig. 274.
35 to 45 ft. span.
Fig. 275.
40 to 60 ft. span.
Fig. 276.
40 to 60 ft. span.
Fig. 277.
50 to 75 ft. span.
Fig. 278.
40 to 60 ft. span.
Fig. 279.
40 to 60 ft. span.
Fig. 280.
50 to 75 ft. span.

The roof is surmounted by a skylight, supported by a cast-iron standard, and provided with wooden or iron louvres.

With regard to trussed rafter roofs Mr. Matheson says,[1] the "forms just described are marked by an absence of vertical members, and for this reason the

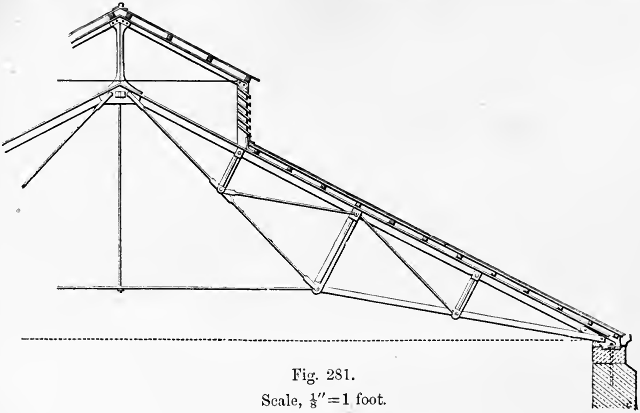


Fig. 281.
Scale, $\frac{1}{8}'' = 1$ foot.

system is not a convenient one for hipped roofs, and for those roofs also where a longitudinal bracing between the principals is required in a vertical plane."

Queen-Rod Roofs.—A form of queen-rod roof suitable for spans of from 30 to 40 feet was given in Part I.

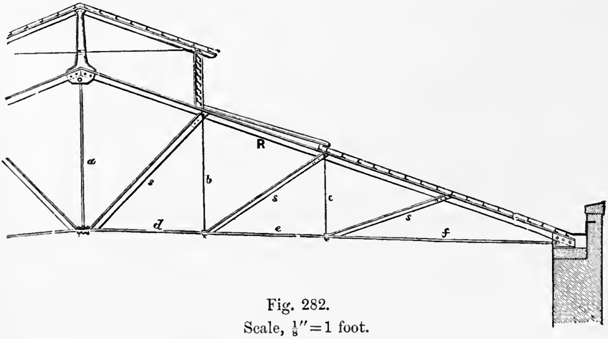


Fig. 282.
Scale, $\frac{1}{8}'' = 1$ foot.

Fig. 282 shows an extension of the same principle adapted for use in roofs of from 40 to 60 feet span.

[1] *Works in Iron.*

In this example the rafters and struts are of T iron, the tension and suspending rods of round iron. The covering is of Duchess slates laid on angle iron laths. The ridge lantern is of similar construction to that last described, covered with slates on angle iron laths, and supported by cast-iron standards.

A side skylight is shown just below the lantern consisting of T iron sash bars, filled in with glass.

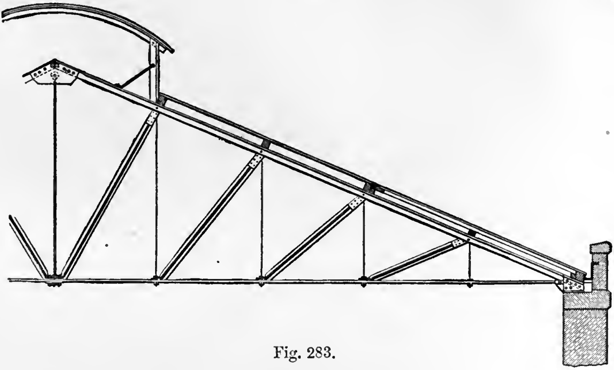


Fig. 283.
Scale, $\frac{1}{10}'' = 1$ foot.

Fig. 283 shows an extension of the form of truss just described, adapted for roofs of from 50 to 75 feet span.

In this case the struts may be of double T iron, riveted back to back, or of double bar or double angle, or double T irons kept asunder by cast-iron distance pieces. The rafters of double angle iron and the purlins of wood sustaining boarding, on which may be laid slates, zinc, or other roof covering.

The lantern is of simple construction, consisting merely of corrugated iron resting upon curved ribs of T iron, and supported by T iron side standards.

The lower portion of the roof slope is covered by an ordinary wooden sash skylight resting upon the purlins.

Modification of Queen-Rod Roof.—Fig. 284 shows a modification of the queen-rod roof often used in practice.[1]

In this form of roof the struts are at right angles to the rafter, and are therefore of minimum length.

In the example given the struts are of double bar iron of the

[1] This example was taken from the roof of a drill shed.

construction described at page 158, the rafters of T iron, the

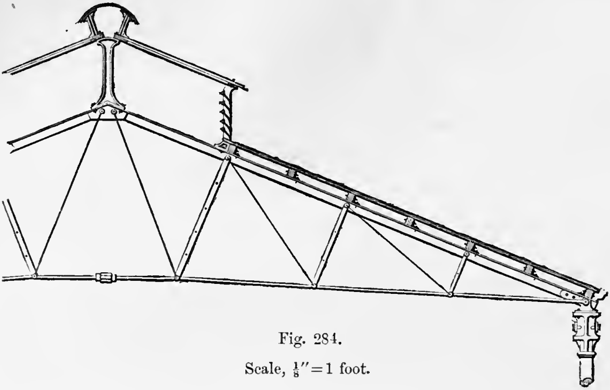


Fig. 284.

Scale, $\frac{1}{8}'' = 1$ foot.

tension and tie rods of round iron, the purlins of wood connected to the rafters by angle iron.

The skylight is shown on a larger scale in Fig. 307, page 166, and is there described.

The tie rod is attached to chairs formed upon the heads of the columns supporting the roof (see Figs. 304, 305), and is provided with a union joint in the centre by which it may be tightened.

PARTS OF IRON ROOF TRUSSES.

The methods of constructing the different parts for iron roofs of small span have already been described in Part I. This section will be confined to the consideration of the forms to be given to members of somewhat larger roof trusses.

Principal Rafters.—It has already been mentioned in Part I. that the principal rafters of an iron roof of small span are generally of T shaped section.

Bars of similar sections, but of larger dimensions, are also used for larger roofs; but in these many other forms are also adopted, a few of which may now be mentioned.

Rafters of I section have been sometimes used for spans of over 60 feet, but are not convenient for the attachment of the struts.

When T iron is used for larger roofs the upper flange may be strengthened by adding plates to it, as in Fig. 285.

Fig. 285.

"Bulb iron with a thin web and a bulb somewhat larger than the top table, gives a greater resistance with the same weight of metal than T iron, but its cost is considerably greater, and it is not quite so easy to connect with the other part of the truss."[1]

The increased strength required in long rafters has sometimes been given without increasing the depth of the iron used by placing two bars side by side, parallel to one another, and kept an inch or two apart by means of cast-iron distance pieces.

Double channel iron may be similarly used, thus—

Fig. 286.

or double angle iron, thus—

Fig. 287.

the latter are the more convenient for connecting with the heads of struts, etc.

Hip Rafters may be strengthened by the introduction of additional flat plates, thus— without much increasing the bulk of the rafter.

Fig. 288.

Purlins for roofs of from 40 to 60 feet span may be of timber (Fig. 284); of angle iron (Fig. 282); T iron, or channel iron, as already described and illustrated in Part. I. The angle and channel iron may be filled in with wood (Fig. 290) in order that the roof covering may be more easily attached.

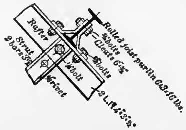


Fig. 289.

In larger roofs, where the principals are widely spaced, the purlins may be of I iron (Fig. 289), or trussed (see Plate IX. Fig. 345).

Struts.—The forms of wrought-iron struts described in Part I., viz. those made of angle or T iron, are frequently used for roofs of spans up to 40 or 60 feet.

A better form, however, is the strut of cruciform section, consisting of two T irons riveted back to back, as in Fig. 281.

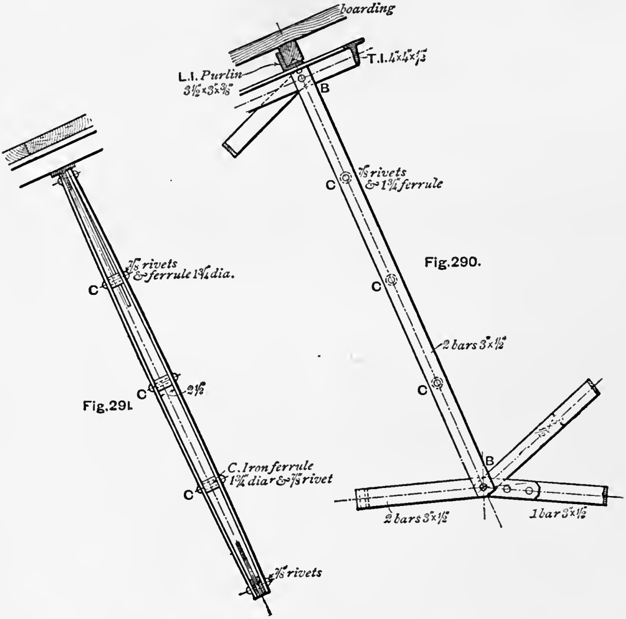
Strong and light struts formed out of wrought-iron gas tubing fitted with cast-iron sockets at the ends are sometimes used.

Another very good form was noticed in Part I. It consists of

[1] Wray's *Theory of Construction.*

two flat bars, Figs. 290, 291, kept apart by cast-iron distance pieces, *c c c*, varying in length so as to form a strut tapering from the centre toward the ends.

Such a strut is shown in Fig. 284, also in Plates VII. IX., and a similar one on an enlarged scale in Figs. 290, 291. L or T irons are sometimes substituted for the flat bars.



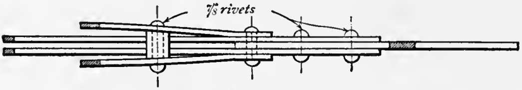


Fig.292. (ENLARGED SCALE) PLAN AT B.

Scale for Figs. 290, 291, ½ inch = 1 foot.
" " Figs. 292 1 inch = 1 foot.

In very large roofs a strut on the same principle as the last mentioned may be constructed by using 4-angle irons kept apart by cross-shaped distance pieces. These crosses are made smaller and smaller as they approach the ends of the strut, which is therefore shaped somewhat like a weaver's shuttle, being wide in the middle and tapering towards its extremities.

Tie and Tension Rods in large roofs are of circular rod iron, or flat bars, as already described for smaller roofs—and are secured in a similar manner. T iron tie rods are very convenient for connections (see Plate XI.)

Flat bars, both single and double (Fig. 291), are more common in large than in small roofs, and have the advantage of being less liable to sag than circular rods of the same tensile strength.

Steel tie rods are now much used.

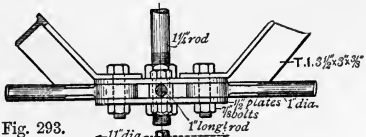


Fig. 293.

Detail at Centre

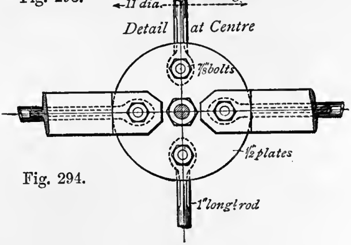


Fig. 294.

Joints in Tie Rod.—When a tie rod is long it is severed at the centre, sometimes at two or more points. The joints may in a round tie rod be formed as shown in Figs. 293, 294 (which are details of the joint at A, Fig. 311, Plate V.), or as in Figs. 338, 339, Plate VIII. When the tie rod is a T iron or flat bar a very simple joint may be made as in Fig. 295.

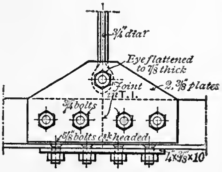


Fig. 295.

Handyside's Patent Couplings.—Plates IX. and X. give several illustrations of joints patented by Messrs. Handyside of Derby for roofs in which steel tie rods are used. The ends of the rods to be connected instead of being forked are bolted to steel straps of the form shown in Fig. 354. This has the great advantage of avoiding eyes, forks, or heads, which would be more difficult to form on steel rods than on those of iron. Moreover

the joint is compact and neat in appearance, and each portion of the tie rod can be adjusted to the exact length required by merely turning it round.

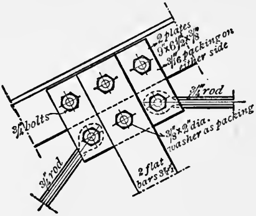
Coupling Boxes.—The tie rod should be so arranged with coupling boxes (see Part I.) or cottered joints that it can be altered in length in order to set up the roof when required.

In large roofs it is an advantage to arrange the tension rods in the same way, either with union screws—cottered joints—or with reverse screws at either end, so that by revolving the rod the screws turn opposite ways, and lengthen or shorten the rods.

These shackles, etc., are not shown in the small scale figures. They are often omitted in practice, the result being that the tension rods either become slack or undergo a greater stress than they are intended to bear.

Connections at Heads and Feet of Struts.—Several forms of these are shown in Figs. 290, 291, 293, 294, 295, also in

Fig. 296.



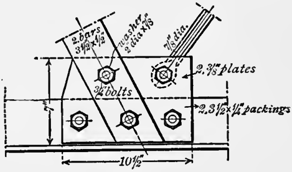


Fig. 297.

Plates V. VII. VIII. IX. X. XI. XII. They require no explanation. Figs. 296, 297 show simple forms constructed with plates.

Suspending Rods for large roofs are similar in every respect to those described in Part I., and nothing more need be said regarding them.

Shoes and Heads.—The lower extremities of principal rafters are sometimes secured in cast-iron shoes with cottered joints, as already explained in Part I. Cast-iron heads are seldom used for large roofs.

Illustrations of cast-iron shoes are given in Part I., also in Figs. 319, 320, 321, Plate VI., and in Figs. 328, 329, 330, Plate VII.

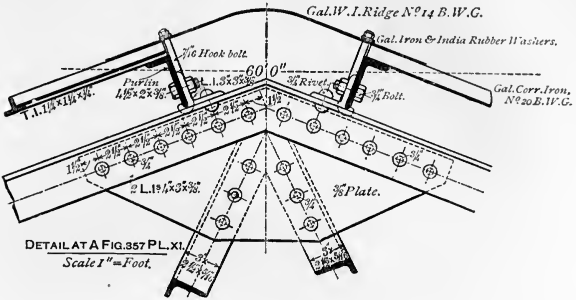


Fig. 298.

Simpler joints are formed by the use of flat wrought-iron plates, to which the parts to be connected are bolted or riveted. When

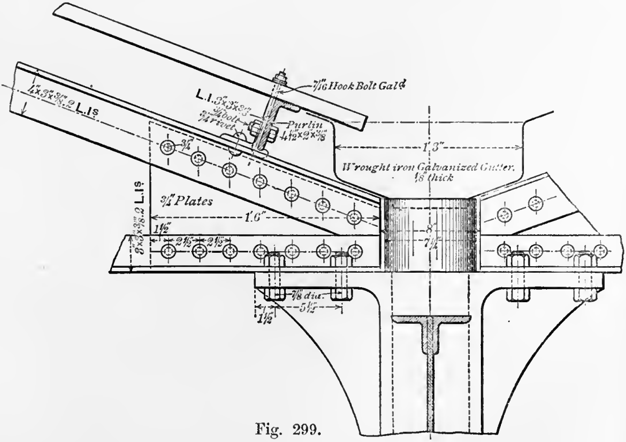


Fig. 299.

the principal rafter is of two angle irons one plate may be inserted between them, as in Figs. 298, 299, which are details of the joint A of the roof, Plate XI, and of Fig. 367, Plate XII. When the principal rafter is of T iron then two plates may be used, one

on each side of the web, as in Fig. 337, Plate VIII., and Figs. 350, 351, Plate X.

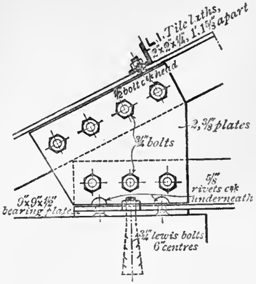


Fig. 300.

Fig. 300 is a simple joint with plates connecting the foot of the principal rafter with a tie of T iron.

Expansion and Contraction Arrangements.—Iron expands or contracts about $\frac{1}{150000}$ of its length for every degree on the Fahrenheit scale.

It is therefore important to make provision in all large roofs for the expansion and contraction caused by changes of temperature.

This is generally done by leaving one end of the truss free to move horizontally.

In roofs of great span the chair or saddle at the free end of the truss is supported on oiled rollers, so that it can move outwards and inwards with ease under changes of dimension caused by the effects of temperature.

In smaller roofs the same object may be attained by supporting the chair on a sheet of lead, and making the holes for the bolts which secure it, slots of an oblong form, so that the chair can move slightly backward and forward on the lead.

It is better to fix the end from which the heaviest gales are most likely to blow.

"In countries liable to hurricanes extra precautions must be taken, and not only should the roof be strongly braced together by wind ties, but the entire structure should be well anchored to the ground. The latter precaution is especially necessary in buildings open at the sides or ends, and liable therefore to severe wind pressure below the roof."[1]

Fig. 301 shows the arrangement adopted to allow for expansion and con-

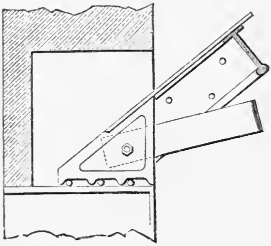


Fig. 301.

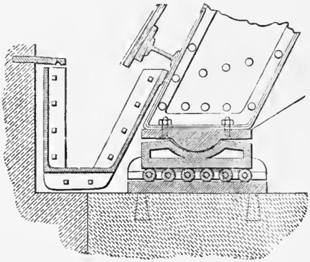


Fig. 302.

traction in the roof over the former Lime Street Station, Liverpool, the details of which will be found in Dempsey's *Railways*, or in his work on *Iron Roofs*.

[1] *Works in Iron*, by Ewing Matheson.

The objection to this arrangement is that when the principal rafter is depressed under the force of the wind, an uneven stress comes upon the joint, the roller on the inner side is more compressed than the others and is liable to be crushed. To prevent this the joint may be formed as in Fig. 302, which shows the expansion arrangement adopted for the roof of the Cannon Street Railway Station.[1] The junction of the roof with the upper part of the casting which rests upon the rollers is hinged with a circular joint, so that, whatever the inclination of the principal rafter may be, the stress passes through the centre of the group of rollers and is distributed evenly over them.

Attachment to Columns.—Iron roofs covering railway stations, sheds, etc., very frequently rest either one or both sides on the heads of iron columns.

The attachment of the foot of the rafter to the head of the column is effected in several different ways; one or two of which will now be described.

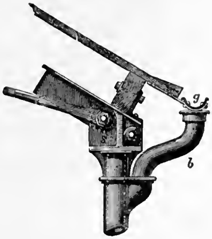
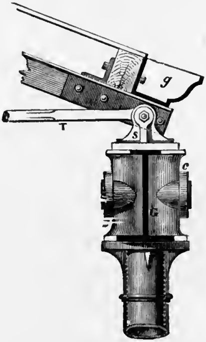


Fig. 303.

Fig. 303 shows the head of a column supporting a small roof. The shoe, *s*, which receives the foot of the rafter, is cast in one piece with the column. The swan-neck bend, *b*, receives the water from the gutter, *g*, and conveys it into the column, which acts as a down pipe.

Fig. 304 is a side elevation, and Fig. 305 is a front elevation,



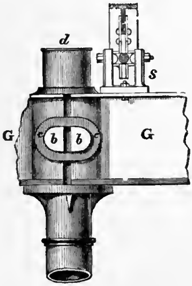


Fig. 304. Scale, $\frac{1}{2}$ inch = 1 foot. Fig. 305.

showing the method by which the roof described in page 157 is supported.

[1] Humber's *Record of Modern Engineering*, 1866.

In this case the chair, *s*, is a distinct casting, and bolted on to the girder close to the head of the column.

The intervals between adjacent columns are spanned by cast-iron girders, G, the ends of which are swelled out and brought round so as to grasp the head of the column.

On the ends of these girders are cast burrs, *b*, and round these is a coupling link, *c c*, of wrought-iron, so as to hold the girders together.

In this case the gutter, *g*, discharges through the socket *d*, down the interior of the column.

The socket prevents the chair from being placed immediately on the head of the column; it is necessarily a little on one side, as shown at *s*, which theoretically is a bad arrangement, as it causes an extra bending stress upon the girder; practically, it is so close to the support that this does not very much matter.

Wind Ties are long rods passing from the foot of a principal rafter diagonally across three or four trusses, to which they are secured, until they reach the ridge; they are generally arranged so as to converge in pairs, as shown in Fig. 306, and should be furnished with union or cottered joints, so that they may be adjusted as to length: these joints are not shown in the figure. Details showing the connection of the wind ties to the rafter are given in Fig. 327, Plate VII.

Such tie rods should be fixed to all large iron roofs, to secure

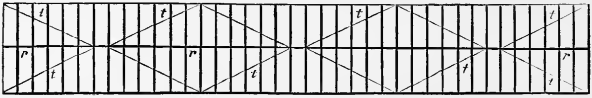


Fig. 306.

them against the effects of gales blowing at an inclination to the length of the roof.

They are hardly necessary when the gables of the building are of solid masonry, but in many cases, even when the roof is not hipped, the gable end is merely filled in with glass, and they are then required.

Lanterns and Ventilators.—The variety of forms of these is very great; one or two different kinds are shown in the accompanying illustrations.

In Fig. 283 a large ventilator is formed with vertical T iron

side standards, and covered with corrugated iron supported upon curved T iron rafters.

In Fig. 282 the ventilator has a central cast-iron standard in addition to T iron standards on each side, the latter being filled in with wooden louvres. The covering to the ventilator is the same as that of the roof, *i.e.* slating on boards fixed to angle irons filled in with wood.

Plate VII. gives details of a lantern-skylight, flat skylight, and ridge ventilator.

Fig. 307 is an enlarged section of the lantern and ventilator surmounting the roof in Fig. 284.

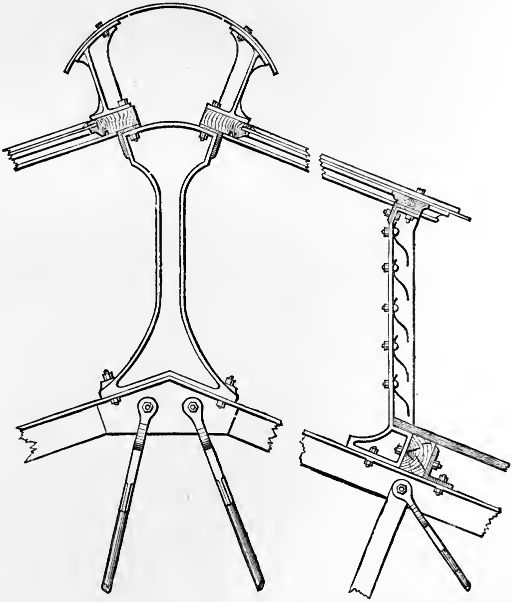


Fig. 307.
Scale, $\frac{1}{2}$ inch = 1 foot.

The construction is evident from the figure, and requires but little explanation.

The skylight itself is supported by a central cast-iron standard bolted to the head, which receives the rafters, and has side

standards of the same material, with galvanised iron louvres. It is covered by an ordinary wooden skylight sash, having deep bars filled in with glass.

Surmounting the skylight is a ventilator open at the sides, which are formed by cast-iron standards, supporting a covering of corrugated iron bolted to flanges formed upon their upper extremities.

Coverings for Iron Roofs.—The coverings used for wooden roofs have already been described at p. 140, Part I., and p. 61, Part II.

Most of these can be used for iron roofs, in some cases with slight modifications in the way of laying.

Slating.—Duchess or other large slates are very often used for iron roofs, and they may be laid either upon boards, or upon angle iron laths, as described in Part I.

Tiling of all kinds may also be used, laid upon laths in the same manner as slating.

Corrugated Iron may be used in the shape of an arch to form the roof itself, without supporting trusses, as mentioned at p. 61; or it may be arched and supported by curved angle or T irons; or it may be laid in sheets upon regular trusses of any form.

The sheets may be laid with the corrugations running either way, either horizontally or down the slope of the roof; the latter arrangement is much to be preferred.

The sheets are of course strongest in the direction of the length of the corrugation; the strength depends upon the depth of the corrugation, thickness of iron, etc.; and in this direction they may be left to span spaces of from 8 to 15 feet without support.

If the corrugations run up and down the slope of the roof, the sheets are supported upon purlins; if the corrugations are horizontal, the sheets rest upon the principals themselves, or when these are widely spaced, upon secondary rafters.

Zinc may be laid upon boarding with wooden rolls, as described at p. 63; or on the Italian system, as described at p. 65.

Lead is now very seldom used in iron roofs, having been almost entirely superseded by zinc.

Glass is a good deal used in large skylights,[1] which often form a considerable portion of the slope of the roof, and run nearly throughout its length.

[1] For glazing without putty see p. 204.

It is also, in large roofs, extensively used upon the "*ridge-and-furrow*" system. This consists in forming small Λ roofs between the secondary rafters, which rest upon the purlins. The ridges of these small roofs generally run horizontally, and their slopes drain into gutters, lying along the upper flanges of the secondary rafters.

Designing Iron Roofs.[1]—In designing an iron roof it should be borne in mind that as many of the braces as possible should be in tension, and the struts should be as short as possible.

When there are only a few purlins widely spaced on the principal rafters, they should be immediately over the joints of the bracing of the roof, so as to prevent bending strains as much as possible.

In such a case the principal rafter is in compression throughout its length.

When, however, the weight is distributed throughout the length of the rafter by means of a number of small purlins, the principal rafter is subjected also to a transverse strain.

In either case the struts should not be so far apart as to necessitate the rafter being of too large a section for economy.

Elaborate forgings should be avoided, and all joints should be as simple as possible. The cast-iron connections between struts and ties so common in old roofs should be avoided.

"For a tensile strain it is safest to have bolts instead of rivets, and sometimes if much depends upon their strength bolts with a nut at each end, so as to avoid the risk of a flaw in the forming of the bolt head."

"In the main tension rods of a roof screwed ends at all the points of connection are advantageous, welds are also so avoided, and there is an opportunity for adjustment."[1]

Care should be taken in designing a roof to use such forms, sections, and scantlings of iron as can be readily found in the market. Sections of peculiar dimensions, though perhaps a little lighter than the nearest sections kept by manufacturers, will not only cause delay but cost more.

"In a roof which is rectangular in plan the distance apart of the principals should be from $\frac{1}{8}$ to $\frac{1}{4}$ the span, and if these limits be overstepped there will be an unprofitable employment of material."[2]

It is sometimes economical to adopt the larger rather than the smaller interval, because, when the trusses are widely spaced, there is necessarily a large cross section given to the struts, but

[1] From Part I. [2] Matheson.

their length remains the same, they are, therefore, less liable to buckle under the thrust that comes upon them, and thus more resistance is obtained from an equal weight of metal.

A hipped roof is more expensive than one with gable ends, but the hipped end is a considerable support to the roof, and itself offers much less resistance to the wind than a gable.[1]

Trusses which do not contain vertical members are not so suitable for hipped roofs as those having such members.

Contract Drawings of Iron Roofs.

Plates V. to XII. are reduced copies of part of the contract drawings for some roofs recently constructed.

There is no object in describing them in detail, but it should be mentioned that Plates XI. and XII. are inserted by the kind permission of Sir Alexander Rendel, K.C.I.E., and the remaining plates by that of Messrs. Handyside and Co.

The student will derive more benefit by carefully studying these practical drawings of well-designed roofs than from representations of roofs drawn merely to illustrate the text.

TABLE OF SCANTLINGS OF IRON ROOFS[2] (from actual practice).

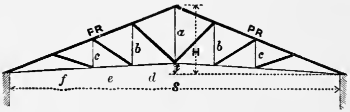


Fig. 308.

Rise, $H = \frac{s}{5}$. Rise of Tie Rod, $t = \frac{s}{45}$. Principals 6 feet 8 inches apart

Span, *s.*	Rafter, PR.	Struts, S.	King Bolt.	Queen Bolt.		Tie Rod.		
In feet.	T iron.	T iron.	*a.*	*b.*	*c.*	*d.*	*e.*	*f.*
	Inches.	Inches.						
20	$2\frac{1}{2} \times 2 \times \frac{3}{8}$	$2 \times 2 \times \frac{3}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	..	$\frac{5}{8}$	$\frac{3}{4}$	..
25	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{3}{8}$	$2 \times 2 \times \frac{3}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	1	...
30	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	1	$\frac{3}{4}$	$\frac{5}{8}$	1	$1\frac{1}{8}$	..
35	$3 \times 2\frac{3}{4} \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	1	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
40	$3\frac{1}{2} \times 3 \times \frac{1}{2}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
45	$4 \times 3\frac{1}{2} \times \frac{1}{2}$	$3 \times 3 \times \frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
50	$4 \times 3\frac{1}{2} + \frac{5}{8}$	$3 \times 3 \times \frac{5}{8}$	$1\frac{3}{4}$	1	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
55	$5 \times 4\frac{1}{2} \times \frac{5}{8}$	$4 \times 4 \times \frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
60	$5 \times 4\frac{1}{2} \times \frac{3}{4}$	$4 \times 4 \times \frac{5}{8}$	$1\frac{3}{8}$	$1\frac{1}{8}$	1	$1\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{3}{4}$

[1] Maynard.

[2] From Molesworth's *Pocket Book.*

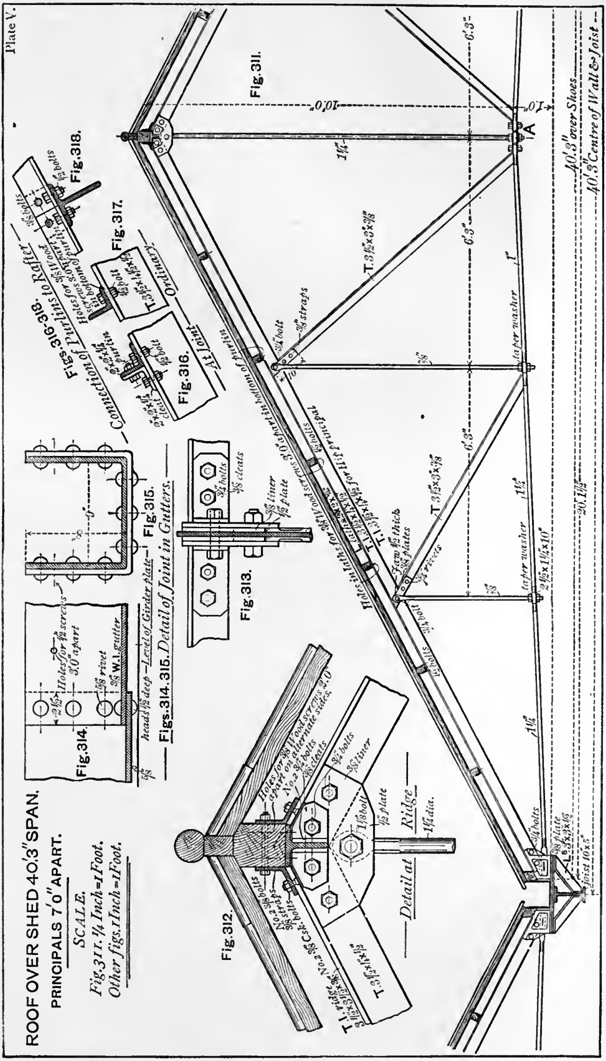


Plate V.
ROOF OVER SHED 40.3" SPAN.
PRINCIPALS 7'0" APART.
SCALE.
Fig. 311. 1/4 Inch = 1 Foot.
Other figs. 1 Inch = 1 Foot.
Fig. 311.
Fig. 312.
Detail at Ridge
Fig. 313.
Fig. 314.
Fig. 315.
Figs. 314. 315. Detail of Joint in Gutters.
Level of Girder plate
Fig. 316.
At Joint
Fig. 317.
Ordinary
Fig. 318.
Figs. 316-318. Connection of Purlins to Rafter
40.3" over Shoes
40.3" Centre of Wall & Joist
joist 10 x 5
taper washer
A

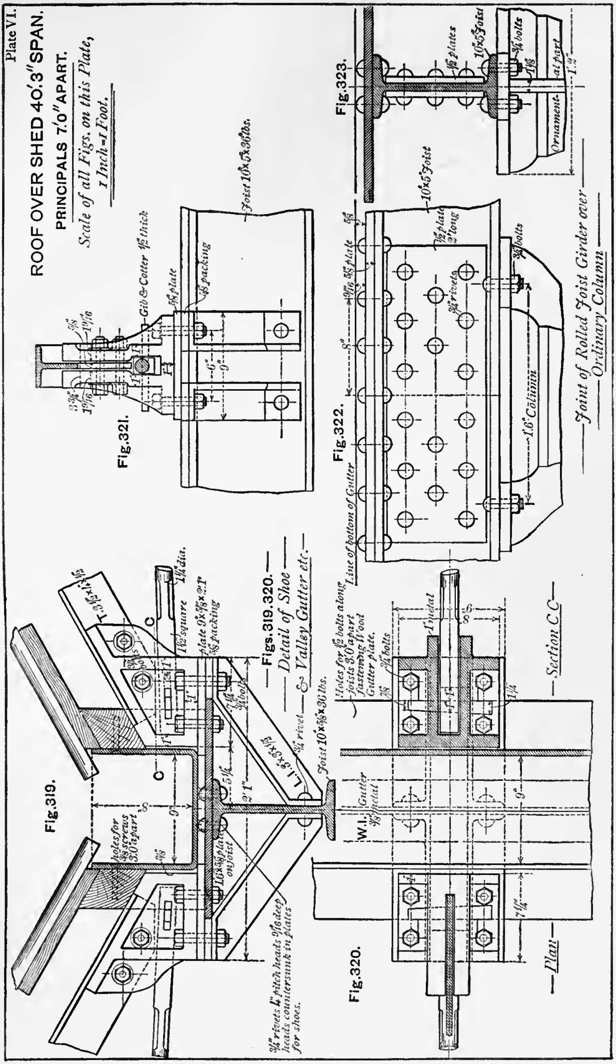


Plate VI.
ROOF OVER SHED 40′.3″ SPAN.
PRINCIPALS 7′.0″ APART.
Scale of all Figs. on this Plate,
1 Inch = 1 Foot.
Fig. 319.
Fig. 320.
Fig. 321.
Fig. 322.
Fig. 323.
Figs. 319. 320.
Detail of Shoe
& Valley Gutter etc.
Joint of Rolled Joist Girder over
Ordinary Column
Section C C
Plan
Gib & Cotter ½″ thick
⅝″ plate
⅜″ packing
Joist 10″×5″×36 lbs.
Joist 10″×5⅝″×36 lbs.
10″×5″ Joist
Line of bottom of Gutter
1′.6″ Column
¾″ bolts
¾″ rivets
Ornament
1½″ square
1¼″ dia.
plate 9″×⅝″×2′.1″
⅜″ packing
¾″ rivet
W.I. Gutter ⅜″ metal
1″ metal
holes for ⅜″ screws 3.0″ apart
Holes for ½″ bolts along joists 3.0″ apart fastening Wood Gutter plate.
¾″ rivets 4″ pitch heads 9/16″ deep heads countersunk in plates for shoes.
C
C

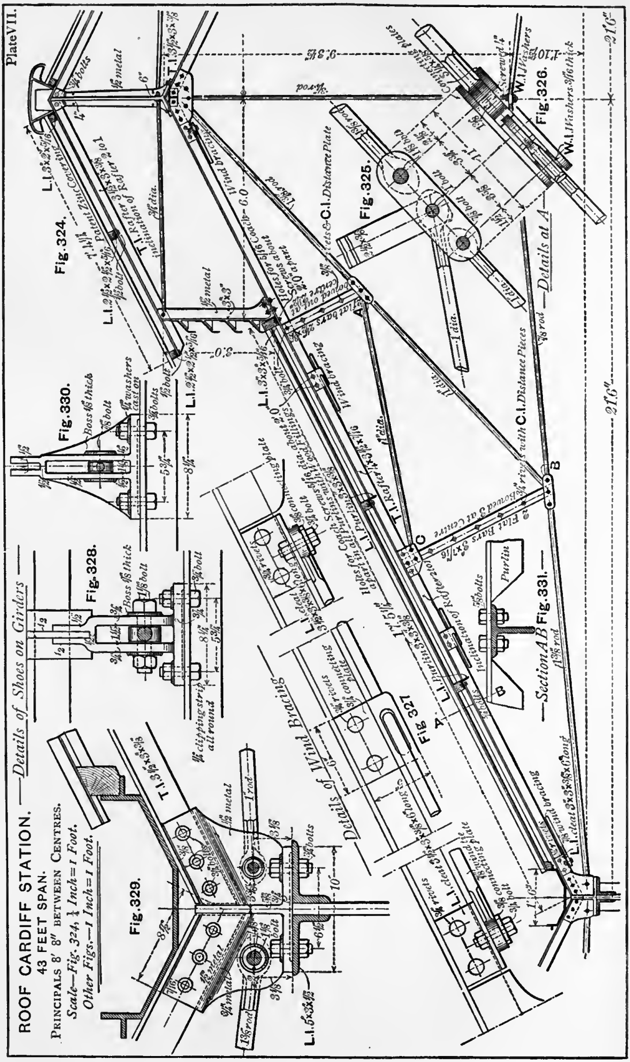


Plate VII.
ROOF CARDIFF STATION.
43 FEET SPAN.
PRINCIPALS 8' 8" BETWEEN CENTRES.
Scale—Fig. 324, ¼ Inch=1 Foot.
Other Figs.—1 Inch=1 Foot.
—Details of Shoes on Girders—
Fig. 324.
Fig. 325.
Fig. 326.
Fig 327
Fig. 328.
Fig. 329.
Fig. 330.
Fig. 331.
—Details of Wind Bracing—
—Details at A—
—Section AB—
21'6"

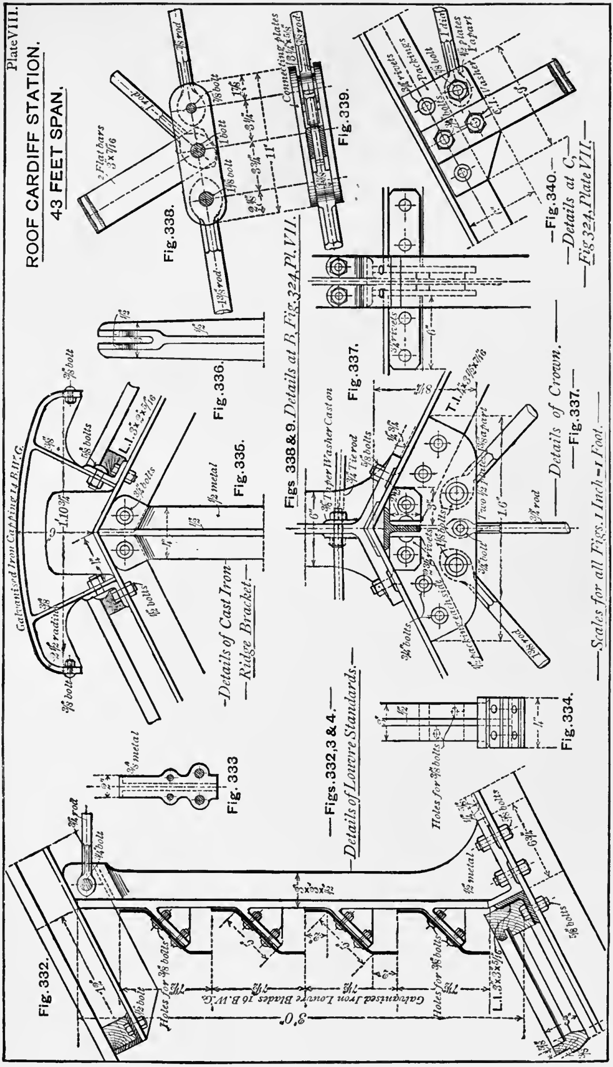
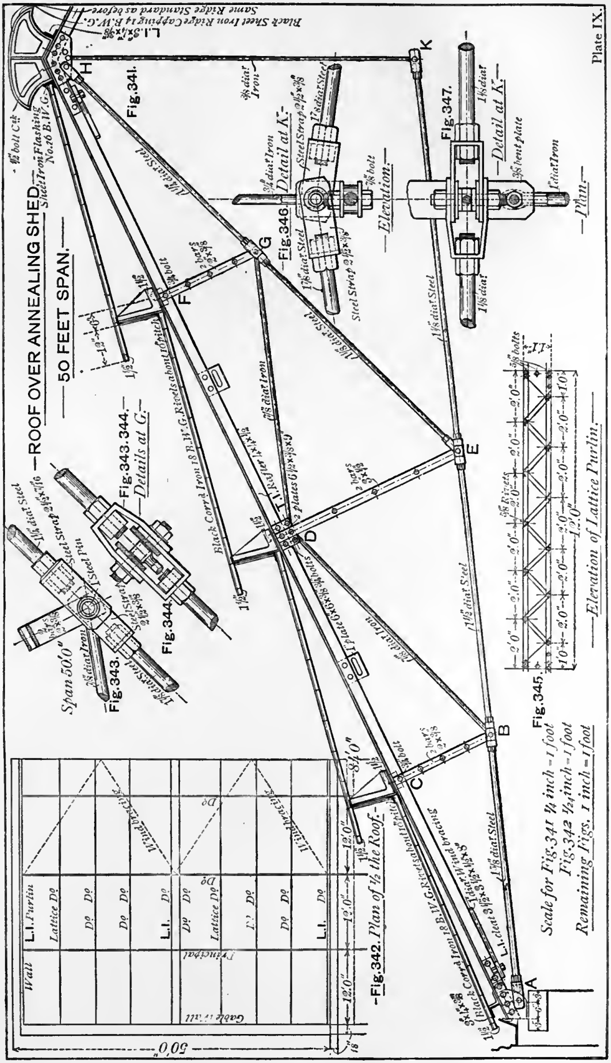


Plate VIII.
ROOF CARDIFF STATION.
43 FEET SPAN.
Fig. 338.
Fig. 339.
Figs 338 & 9. Details at B, Fig. 324, Pl. VII.
Fig. 340.
Details at C,
Fig 324, Plate VII.
Fig. 336.
Fig. 335.
Details of Cast Iron
Ridge Bracket.
Fig. 337.
Details of Crown.
Fig. 337.
Scales for all Figs. 1 Inch = 1 Foot.
Fig. 333
Figs. 332, 3 & 4.
Details of Louvre Standards.
Fig. 334.
Fig. 332.
Galvanised Iron Louvre Blades 16 B.W.G.
Galvanised Iron Capping 14 B.W.G.


ROOF OVER ANNEALING SHED.
50 FEET SPAN.
Fig. 341.
Fig. 342. Plan of ½ the Roof.
Fig. 343. 344. Details at G.
Fig. 345. Elevation of Lattice Purlin.
Fig. 346. Detail at K. Elevation.
Fig. 347. Detail at K. Plan.
Span 50'0"
Scale for Fig. 341 ¼ inch = 1 foot
Fig. 342 1/24 inch = 1 foot
Remaining Figs. 1 inch = 1 foot
Plate IX.

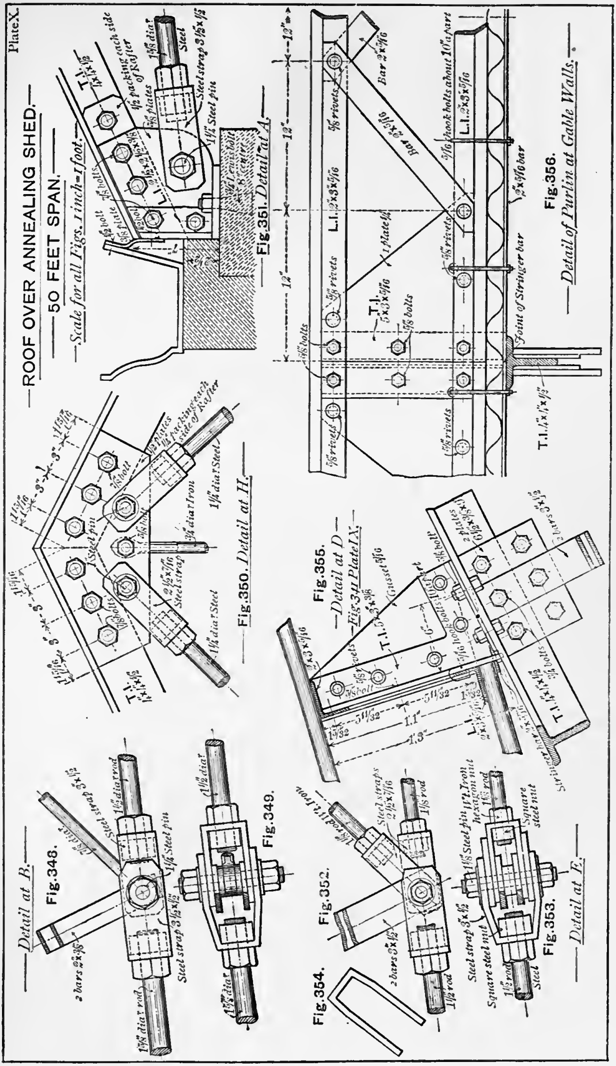
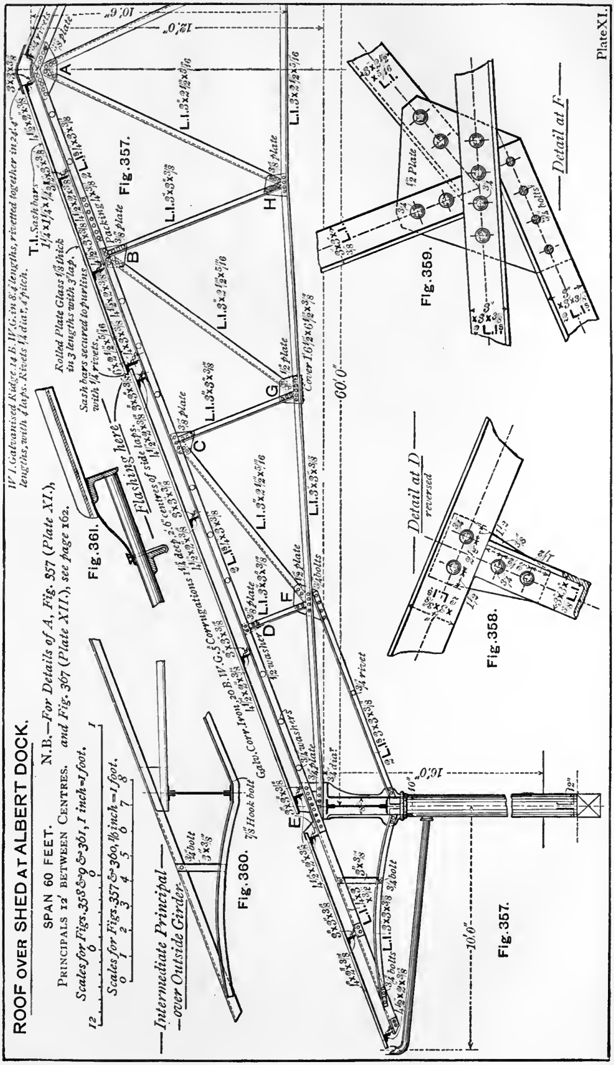


Plate X.
ROOF OVER ANNEALING SHED.
50 FEET SPAN.
Scale for all Figs. 1 inch = 1 foot.
Fig. 351. Detail at A.
Fig. 350. Detail at H.
Fig. 356.
Detail of Purlin at Gable Walls.
Fig. 355.
Detail at D
Fig. 341 Plate IX.
Detail at B.
Fig. 348.
Fig. 349.
Fig. 352.
Fig. 353.
Detail at E.
Fig. 354.


ROOF OVER SHED AT ALBERT DOCK.
SPAN 60 FEET.
PRINCIPALS 12' BETWEEN CENTRES.
N.B.—For Details of A, Fig. 357 (Plate XI.), and Fig. 367 (Plate XII.), see page 162.
Scales for Figs. 358 & 9 & 361, 1 inch = 1 foot.
Scales for Figs. 357 & 360, 1/8 inch = 1 foot.
Intermediate Principal over Outside Girder.
Fig. 360.
Fig. 361.
Flashing here
Fig. 357.
Fig. 358.
Detail at D reversed
Fig. 359.
Detail at F
60'0"
Plate XI.

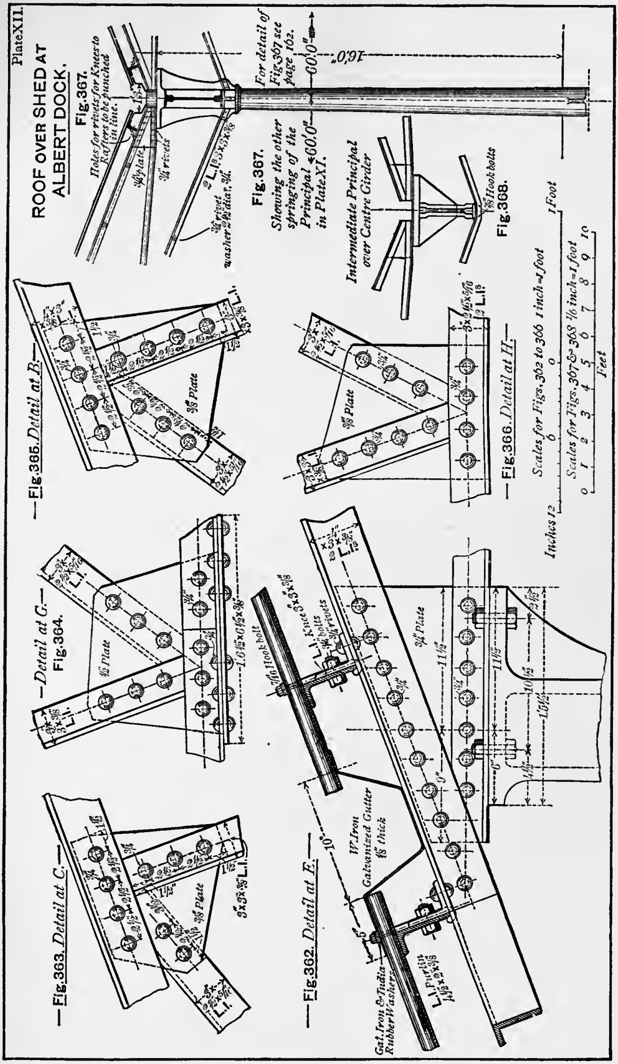


Plate XII.
ROOF OVER SHED AT ALBERT DOCK.
Fig. 367.
Holes for rivets for Knees to Rafters to be punched in line.
For detail of Fig. 367 see page 162.
Fig. 367.
Showing the other springing of the Principal 60'0" in Plate XI.
Intermediate Principal over Centre Girder
Fig. 368.
⅞ Hook bolts
Fig. 365. Detail at B.
⅜ Plate
Fig. 366. Detail at H.
⅜ Plate
Scales for Figs. 362 to 366 1 inch = 1 foot
Scales for Figs. 367 & 368 1/16 inch = 1 foot
Inches 12
1 Foot
Feet
Detail at G.
Fig. 364.
½ Plate
Fig. 362. Detail at E.
W. Iron Galvanized Gutter ⅛" thick
¾ Plate
L.I. Purlin
Gal. Iron & India Rubber Washers
Fig. 363. Detail at C.
⅜ Plate

CHAPTER VIII.

PLASTERERS' WORK.

Plastering consists in applying different compositions resembling mortar to walls and ceilings, in thin layers, so as to form smooth surfaces, for the sake of appearance and cleanliness.

The plaster may either be laid on the face of the wall itself, or it may be spread over a screen of laths fixed in any required position.

The latter operation only is technically known as "*plastering*," the application to the wall itself being called "*rendering*."

Plastering and rendering are applied in one, two, or three coats, according to the importance of the building and the degree of finish required.

Materials used by the Plasterer.—The materials used for plastering will be fully described in Part III.

In the following brief notes information is given sufficient only to enable the student to understand the processes described in this chapter.

LIMES AND CEMENTS.—*Lime.*—The pure or fat limes are generally used for plastering, because in using hydraulic limes minute unslaked particles are apt to get into the work, and to *blow*, throwing out bits of plaster, and injuring the surface.

Plaster of Paris is calcined gypsum. When mixed with water to form a paste it sets very quickly, expanding as it sets, and attains its full strength in an hour or two.

Portland Cement is made from chalk and clay mixed together in water, then burnt and ground. It is the strongest cement in use, but sets more slowly than the other varieties.

Roman Cement, Medina Cement, Harwich, Calderwood, Whitby, Mulgrave's, and Atkinson's Cement, are all natural cements of the same description. They are made by burning nodules found in different geological formations. These cements set very rapidly, but attain no great ultimate strength.

Keene's, Parian, Martin's, and *Robinson's Cements,* are all manufactured by recalcining plaster of Paris with different substances.

These cements are useful only for indoor work; they set very quickly, and can be painted within a few hours.

Whiting is made by grinding white chalk to a fine powder.

SAND AND WATER.—Very clean sand and fresh water should be used for plasterers' work (see Part III.)

MIXTURES.—*Coarse Stuff* is a rough mortar, containing 1 or $1\frac{1}{2}$ part of sand to 1 of lime by measure, thoroughly mixed with long ox hair (free from grease and dirt), in the proportion of 1 lb. hair to 3 cubic feet of mortar.

Fine Stuff is pure lime slaked with a small quantity of water, and afterwards saturated until it is of the consistence of cream; it is then allowed to settle and the water to evaporate, until thick enough for use. For some purposes a small quantity of white hair is added.

Plasterers' Putty is lime dissolved in water, and then run through a hair sieve. It is very similar to fine stuff, but prepared somewhat differently, and always used without hair.

Gauged Stuff consists of from $\frac{3}{4}$ to $\frac{4}{5}$ plasterers' putty, and the remainder plaster of Paris. The last-named ingredient causes the mixture to set very quickly, and it must be gauged in small quantities. The proportion of plaster used depends upon the time to be allowed for setting, the state of the weather, etc., more time required in proportion as the weather is damp.

For cornices the putty and plaster are often mixed in equal proportions.

Stucco is a term vaguely applied to many mixtures containing common and hydraulic limes, also to some cements.

Common Stucco contains three or four parts sand to one of hydraulic lime.

Trowelled Stucco consists of $\frac{2}{3}$ fine stuff (without hair), and $\frac{1}{3}$ very fine clean sand.

Bastard Stucco is of same composition as trowelled stucco, with the addition of a little hair.

Rough Cast consists of sand, grit, or gravel, mixed with hot lime in a semi-fluid state.

Size is thin glue made by boiling down horns, skins, etc.

Double Size is boiled for a greater time so as to be stronger.

LATHS are thin strips of wood, generally fir, sometimes oak, split from the log, 3 or 4 feet long, about an inch wide, and varying in thickness according to their class.

Single laths	are about . .	$\frac{3}{16}$ inch thick.
Lath-and-half lath	" . .	$\frac{1}{4}$ "
Double laths	" . .	$\frac{3}{8}$ "

Lathing.—Laths to receive plaster may be fixed either in a horizontal position as for ceilings, vertically as a covering for walls and partitions, or in such a manner as to form inclined or curved surfaces.

Lathing Ceilings.—For this purpose the laths are nailed to the underside of the ceiling joists (see Figs. 194 and 228, Part I.), (or in many cases to the bridging joists; see Fig. 192, Part I.), which should, if necessary, be brought into a horizontal plane by adding slips of wood called "firrings."

The laths are fixed parallel to one another, and $\frac{3}{8}$ inch apart so that the intervals afford a key for the plaster. Every lath is secured by nails, one being driven through the lath wherever it crosses a joist or batten. The moist plaster passes between the laths, forming protuberances at the back—these harden and form what is known as the "*key*," which prevents the plaster from falling away from the laths and keeps it in position. Care should be taken that the ends of the laths do not overlap one another, and that they are attached to as small a surface of timber as possible, so that the key may not be interrupted.

If the joists are of wood, a narrow fillet may be nailed along the under side of each to receive the laths, so as to interfere with the key of the plaster as little as possible.

The laths should be laid in "bays," so as to break joint in portions 3 feet wide (see Fig. 369).

The thickest laths should be used for ceilings, and for very important work they should be nailed with zinc nails, so that there may be no danger of their oxidising, and the rust showing on the surface.

Battened Walls[1] are so called because wooden battens about 2 to $2\frac{1}{2}$ inches wide, and from $\frac{5}{8}$ to 1 inch thick, are fixed vertically at central intervals of about 12 inches, to receive the laths.

The battens are nailed to wood plugs in the wall, except where flues occur, in which case they should be secured by iron holdfasts.

The laths are nailed as above described. They should be fully $\frac{3}{4}$ inch clear of the inside of the wall, and about $\frac{3}{8}$ inch apart—thus affording a key which is sufficient to support the plaster in its vertical position.

Lath-and-half laths should be used for walls and partitions subject to rough usage, and single laths for ordinary walls.

Walls likely to be damp should be battened, as the clear air-

[1] Sc. *Strapped walls.*

space between the masonry and the lathing insures the plastered surface being constantly dry; but battened walls harbour vermin, the woodwork is subject to decay, and is injurious in case of fire.

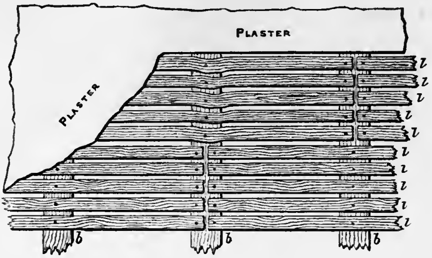


Fig. 369. *Elevation.*

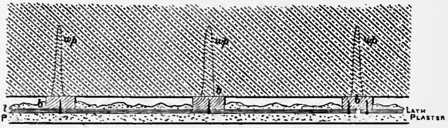


Fig. 370. *Sectional Plan.*

Figs. 369, 370 show a sectional plan and an elevation of a portion of a battened wall, with some of the plaster removed, in order to show the laths *l l* and battens *b b* below.

The laths are shown as breaking joint in bays. This is not absolutely necessary for walls, but is often done in vertical work as well as for ceilings.

Counter-lathing is necessary when plaster has to be applied close to a flat surface, such as that of a large beam. In such a case laths are nailed on to the surface of the beam about a foot apart, and across these is nailed the lathing to receive the plastering.

This second layer of laths is termed *counter-lathing.* Being clear of the surfaces of the beam, a key is afforded, and the plaster adheres to the first layer of laths, which it would not do if they were nailed on to the beam itself.

Brandering is a Scotch term applied to a kind of counter-lathing. It has already been described at page 100, Part I.

Plastering.—ONE-COAT WORK; known as "*Lath and Plaster one Coat;*" or, "*Lath and Lay.*"—This consists of a layer of " coarse

stuff" of an uniform thickness, spread over the laths with a smooth and even surface. The plaster should be stiff enough to hold together, but just sufficiently soft to pass between the laths, being worked well in between them with the point of the trowel, and bulging out behind the laths into excrescences, which form a key, and keep the plaster in position.

This is the cheapest kind of plastering, and is used only in inferior buildings, or behind skirtings, plinths of partition shutters, window backs, etc.

In some parts of the country one-coat work is never used to cover lathing, but only for rendering on walls.

TWO-COAT WORK; described as "*Lath, Plaster, and Set;*" or, "*Lath, Lay, and Set.*"

1*st Coat.*—The first coat is laid upon the laths as above described, but the surface, instead of being smoothed, is roughed over by scratching it with a birch-broom, so as to form a key for the second coat.

Setting.—The second coat, or "setting," is a thin layer of fine stuff, or putty, or gauged stuff, and should not be trowelled on till the first layer is stiff. If the latter has become very dry, it must be moistened before the second coat is applied, or the latter in shrinking will have its moisture sucked out, crack, and fall away. As the fine stuff is laid on, the surface is smoothed by drawing backwards and forwards over it the wet brush used for damping the first coat.

THREE-COAT WORK.—Described as "*Lath, Plaster, Float, and Set;*" or, "*Lath, Lay, Float, and Set.*"

Pricking-up is the name given in this case to the first coat, which is laid as before described; but in order to form a good key for the next coat the surface is scored over with the point of a lath in deep scratches, crossing each other diagonally in sets of parallel lines about 3 or 4 inches apart.

Scratching tools, with several points, are sometimes used.

Floating.[1]—The second, or "floated" coat, is applied when the pricking-up is sufficiently dry to resist pressure.

It consists of fine stuff, with the addition of a little hair, and derives its name from its being laid on with "floats" in the following manner:—

In order to ensure the surface of the plaster being in a true plane, narrow bands or "screeds" of plaster, about 6 or 7 inches wide, are formed at the angles, and at intervals of from 4 to 10 feet

[1] Sc. *Straightening.*

on the wall or ceiling. The surfaces of these are then brought into the required plane by passing long straight-edges over them.

Horizontal screeds for ceilings should moreover be levelled, and vertical screeds "plumbed" up from the skirting grounds (see page 80), before proceeding farther.

The spaces between the screeds are then "filled out" flush with the fine stuff, and smoothed off with straight-edges, or with a large flat board, having two handles at the back, and known as a "Derby float."

The surface is then gone over with a smaller hand float, and any lefects made good by adding a little soft stuff.

Setting.—Before applying the third coat or setting, the floated surface should be scratched over with a broom, and then allowed to become perfectly dry.

The setting is varied in composition to suit the nature of the finish intended for the surface.

If the surface is to be papered, it should be "set with fine stuff;" if it is to be whitened, it should be "set with putty and washed sand;" and if it is to be painted, it should be finished with "trowelled stucco" or plaster.

"Set with Fine Stuff."—For surfaces to be papered the setting coat should be of fine stuff containing a little hair, and the finished work would be described as "Lathed, Plastered, Floated, and Set with Fine Stuff."

"Set with Putty and Plaster."—If the wall or ceiling is to be whitened or coloured, the third coat should be of plasterers' putty mixed with a little fine sand, and sometimes with a little white hair.

If required to set quickly, especially in damp weather, from $\frac{1}{6}$ to $\frac{1}{3}$ plaster of Paris is added to the stuff, which must be gauged (or mixed) in small quantities (see Gauged Stuff, p. 179).

This work, when finished, would be known as "Lathed, Plastered, Floated, and Set with Putty and Plaster;" or it would also come under the general designation of *Gauged Work.*

Great care should be taken to ascertain that the floated coat is dry before this setting is applied, otherwise the coats will shrink unequally, and the last coat will be full of cracks.

Rendering is the term used for the process of applying plaster or cements to the naked surface of walls.

With regard to plaster, it is applied in exactly the same way as upon laths, excepting a slight difference in the first coat.

The surface of the wall to be rendered should be rough so as to form a key to which the plaster will firmly adhere. This may be secured by leaving the mortar joints unstruck and protruding when the wall is built; or the joints may be raked and the face hacked and picked over to give it the necessary roughness.

Rough Rendering is the first coat laid to receive more finished work.

It is of coarse stuff, but contains a little less hair than that used on laths, and is applied in a moister state, which causes it to adhere better to the wall.

The holes and crevices in the wall should be entirely filled up in applying this coat, but the surface of the plaster need not be scratched or scored over.

Floating and Setting are performed in exactly the same way as upon laths.

Gauged Work is formed by the addition of a proportion of plaster of Paris to any coat of plaster, in order to cause it to set more rapidly. Unless the process is very carefully conducted cracks will occur in the plaster. The quantity of plaster added depends upon the rapidity of setting required, the dampness of the weather, etc.

Cornices, Mouldings, and Ornaments, should be as light as possible.

If they do not project more than 2 inches, a backing of coarse stuff will be sufficient to support them; but if the projection is 6 or 8 inches, or more, brackets of wood, roughly cut to the section of the intended cornice, must be fixed along the wall at intervals of 10 or 12 inches. Upon these laths are nailed and "pricked up"—that is, covered with a thick coat of coarse stuff, so that a rough edition of the future cornice is produced. A mould made of zinc, or of beech with zinc or brass edges, is then for the time "muffled" by covering the profile edge with a layer of plaster of Paris about $\frac{1}{8}$ inch thick. The mould is then drawn along over the surface of the rough cornice of coarse stuff already formed. It is guided by battens fixed along the lines where the cornice will cut the ceiling and wall, and the effect produced by it is to remove the superfluous stuff and leave the cornice moulded approximately to the form required, the surface all over being about $\frac{1}{8}$ inch within the intended profile. The muffling is then removed from the mould, and the surface of the cornice covered with gauged stuff, over which the mould is worked until the exact form of the cornice is produced.

As the stuff sets very quickly, it should be frequently sprinkled, and portions between projections or other breaks in the line should be finished off at once.

Where a portion of the moulding projects 3 or 4 inches beyond the general surface, it may be sustained by nails driven into the wall or bracket about 6 inches apart, and connected by tarred string.

Mitres in angles and small breaks are finished by hand, and indentations are left for enrichments, which may be cast in plaster of Paris, or composition, and cemented into their place.

These indentations in the plaster are formed by projections left on the mould.

Ornaments of various kinds are made of plaster of Paris cast in bees'-wax moulds. When large and heavy they should be secured by screws to woodwork.

Carton pierre, or Papier Maché, consisting of paper formed into pulp and forced into moulds, is also used for ornaments. Though not capable of receiving so sharp an outline as plaster of Paris, it is more easily transported without breaking, lighter, easier to fix, and very useful—especially in the country, where skilled workmen to cast plaster ornaments are not easily obtainable.

There are several other materials used for making the mouldings and ornaments required by the plasterer, which it would be beyond the province of these Notes to describe.

Fig. 371 shows a cornice at the angle of a room in sectional elevation.

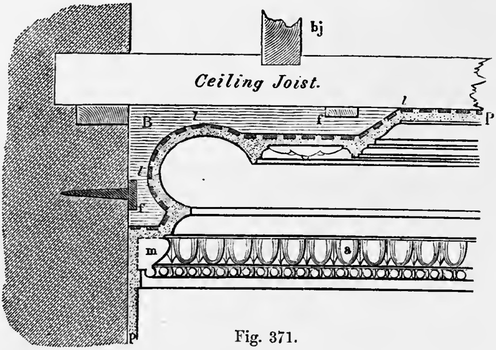


Fig. 371.

B is the rough bracket cut approximately to the shape of the cornice. This bracket is attached to the fillets *f f*, which are

fixed as shown, and carefully levelled. In some cases the bracket is nailed to the bottom or sides of the ceiling joists, and it is very frequently built into the wall, as shown at C in Fig. 372.

l l are the laths nailed to the bracket to form the surface and key for the plastering.

m is the moulding, which is made separately, and fixed (after the cornice is run and set) into the recess left for it, shown in Fig. 371 in dotted lines.

An ornament is also shown in the recess left in the soffit of the cornice. Holes are broken through the plaster forming this soffit, so that the soft plaster at the back of the ornament may pass between the laths themselves, and thus form a key, which secures it directly to the lathing.

The coved portion of the cornice is sometimes formed in papier maché or light plaster casts, and fixed without any supporting brackets, being fitted in between the projecting mouldings above and below, and secured with plaster of Paris.

Large Coved Cornices are supported by brackets or cradling, built up of pieces of board. Two or more are used, according to the size of the cornice, and the surface is covered with lathing, and finished in the same way as small cornices.

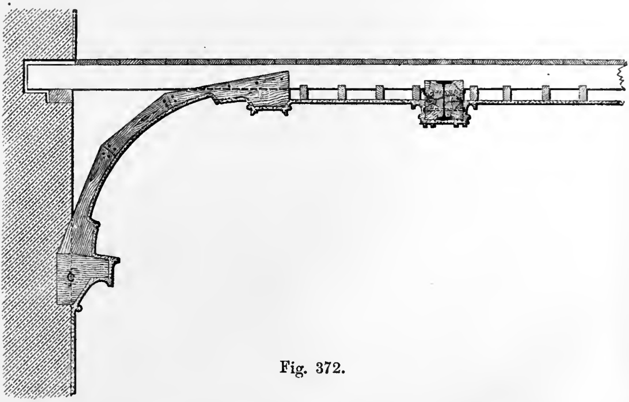


Fig. 372.

Fig. 372[1] shows a bracket built up in three pieces, which abut

[1] The scale of this figure is so small that neither the lathing nor counter-lathing is shown.

against one another, other pieces being nailed over the joints, the upper extremity being nailed to the joists of the floor above, and the lower end resting upon the rough bracket of the projecting cornice below, which is built into the wall.

This figure shows also the method of covering a beam projecting below the surface of the ceiling. The sides and soffit of the beam are counter-lathed, plastered, and decorated by mouldings struck on the plaster, or attached to it.

In some cases the beam is covered with cradling, which makes it up to the size required for the design of the decoration, and, by keeping the laths at a distance, affords a key without counter-lathing.

"Very large projecting mouldings and cornices inside buildings are even made of coarse canvas strained over a light framework, and washed over with gauged stuff. They are easily carried up and fixed in position."[1]

Rendering in Cement.—The wall to be rendered should itself be dry, but the surface should be well wetted, to prevent it from absorbing at once all the water in the cement; it should also be sufficiently rough to form a good key for the cement.

Screeds may be formed on the surface, and the cement should, if possible, be filled out the full thickness in one coat, and of uniform substance throughout.

Any excess of cement in projections, mouldings, etc., should be avoided, by dubbing out with bits of brick.

When cement is put on in two or three coats, the coats already applied should on no account be allowed to dry before the succeeding layers are added.

The coats last applied are very liable to peel off under the effects of frost or exposure.

Many of the quick-setting cements, such as those mentioned below as adapted for internal work, are rendered in one thickness of cement and sand, and the face afterwards finished and brought to a surface with neat cement.

Sand may be added with advantage to most cements, to prevent excess in shrinkage and cracking; sometimes a very large proportion is used (see Part III.)

External Work.—The material best adapted for rendering the external surfaces of walls is Portland cement. Other materials

[1] Seddon's *Notes*.

such as Roman cement, are, however, frequently used, but have not the same adherence, appearance, or weathering properties.

The objection to Portland cement, from an economical point of view, is its first cost, the greater labour required in using it as compared with that necessary for other cements, and also the time frequently wasted upon it, for, in consequence of its setting slowly, there is a tendency for the men to go on working it too long.

In order that it may set as quickly as possible, the less heavy varieties should be selected for rendering (see Part III.)

External rendering is often marked with lines, so as to represent blocks of ashlar stone.

Both Portland and Roman cement are mixed with a good proportion of sand for external work.

The Portland cement may be used in the proportion of 1 cement to 3 sand, and the Roman cement with 1 part of sand to 1 of cement for upright work.

For cornices, mouldings, etc., about half the quantity of sand should be used, but some is required to prevent cracking.

Internal Work.—Parian, Keene's, Martin's cement, and others of a similar character, are eminently adapted for internal work.

The treatment of the several descriptions varies slightly, but they are generally laid in a thin coating of about $\frac{1}{8}$ inch depth on a backing of Portland cement and sand. In some cases the backing is formed of the quick-setting cement itself, mixed with 1 to $1\frac{1}{2}$ of sand.

Most of them can be brought to a beautiful hard polished surface, and are ready to receive paint in a few hours.

These cements are largely used, not only for rendering walls, but for forming skirtings, mouldings, pilasters, angle beads, and other internal finishings of a building.

Portland cement is also used for internal work often with a very large proportion of sand, as much even as 9 parts of sand to 1 of cement being recommended.

Stucco.—*Common Stucco,* composed of $\frac{3}{4}$ sand and $\frac{1}{4}$ hydraulic lime, used to be greatly in vogue for outside work, but has now been almost superseded by the various cements introduced during the last few years.

To receive stucco, the surface of the wall should be rough to form a key, thoroughly wetted, and freed from dust. The stucco is then laid on in a fluid state with a brush, like whitewash, after

which a coat may be applied as in common rendering, unless the work is to be floated, in which case screeds must be formed round the margin of the wall, and vertically, at intervals of 3 or 4 feet throughout its length. These are filled out with stucco, which is smoothed by a straight-edge passed over it to remove any superfluous plaster, and then well rubbed with the hand-float and brought to a hard and glossy surface.

When cornices are to be formed, projecting bricks or tiles must be left to support them. These are covered with stucco, on which the moulding is run as in internal work.

Plaster of Paris quickens the setting of the stucco, but should not be used for outside work, as it will not stand exposure.

Rough Stucco is an imitation of stone. It is spread in a thin coat on a floated ground, which should be in a half-dry state, and is then gone over with a hand-float covered with a piece of felt, which raises the grit of the sand and gives the surface of the work the appearance of stone.

This also has been superseded by cement, which is treated in the same way when it is required to have a rough surface.

Trowelled Stucco, consisting of $\frac{2}{3}$ fine stuff and $\frac{1}{3}$ sand, is worked upon the floated coat, which must be perfectly dry before it is applied. The stucco is beaten and tempered with water until it is of the consistency of thin paste. It is then spread with a large trowel over the surface, to the thickness of about $\frac{1}{16}$ inch, as evenly as possible, and in small portions of about 2 or 3 square yards. The surface is then wetted and rubbed down with the hand-float (being sprinkled with a wet brush during the operation), until a surface is produced as hard and smooth as that of polished marble.

This process is used for surfaces to be painted, and for superior ceilings to be finished white. It is not so strong as the finishing with fine stuff.

Bastard Stucco is, like trowelled stucco, laid upon the second or "floated coat," but it is slightly different in composition, as it contains a little hair, is not hand-floated, and is finished with less labour than the other.

This and trowelled stucco are chiefly used for inside work intended to be painted.

Selenitic Plaster[1] is made by adding a small proportion of plaster of Paris to hydraulic limes, which are then known as "prepared Selenitic Limes."

[1] Selenitic material has been used in the new Imperial Institute.

The effect of this is to stop the slaking of the lime, and to convert it into a kind of cement.

The following instructions for its preparation are from the circular of the patentees:—

"*If prepared in a Mortar Mill.*—1*st,* Pour into the pan of the edge-runner four full-sized pails of water.

"2*d,* Gradually add to the water in the pan 2 bushels of prepared selenitic lime, and grind to the consistency of creamy paste, and in no case should it be thinner.

"3*d,* Throw into the pan 10 or 12 bushels of clean sharp sand, burnt clay, ballast, or broken bricks, which must be well ground till thoroughly incorporated. If necessary, water can be added to this in grinding, which is preferable to adding an excess of water to the prepared lime before adding the sand.

"When the mortar mill cannot be used, an ordinary plasterer's tub (containing about 30 or 40 gallons) or trough, with outlet or sluice, may be substituted.

"*If prepared in a Plasterer's Tub.*—1*st,* Pour into the tub 4 full-sized pails of water.

"2*d,* Gradually add to the water in the tub 2 bushels of prepared selenitic lime, which must be kept well stirred until thoroughly mixed with the water to the consistency of creamy paste, and in no case should it be thinner.

"3*d,* Measure out 10 or 12 bushels of clean sharp sand or burnt clay ballast, and form a ring, into which pour the selenitic lime from the tub, adding water as necessary. This should be turned over two or three times, and well mixed with the larry or mortar hook.

"Both the above mixtures are suitable for bricklayers' mortar or for first coat of plastering on brickwork.

"*N.B.*—Plastering on brick can be floated (or straightened) in one coat, and requires no hair.

"*For Plastering on Lath Work.*—To the same quantities of water and prepared lime, as given, add only 6 or 8 bushels of clean sharp sand and 2 hods of well-haired lime putty; the hair being previously well hooked into the lime putty. When the mill is used, the haired putty should only be ground sufficiently to ensure mixing. Longer grinding destroys the hair.

"Lime putty should be run a short time before being used, to guard against blisters, which will sometimes occur.

"This mixture will be found to answer equally well for ceilings

as for partitions. If the sand is very sharp, use only 6 bushels of sand for covering the lath, and when sufficiently set, follow with 8 bushels of sand for floating (or straightening).

"*Setting Coat and Trowelled Stucco.*—For common setting (or finishing coat of plastering), the ordinary practice of using chalk lime putty and washed sand is recommended. But if a hard selenitic face is required, care must be taken that the prepared selenitic lime be first passed through a 24 by 24 mesh sieve, to avoid the possibility of blistering, and used in the following proportions:—4 pails of water; 2 bushels of prepared selenitic lime (previously sifted through a 24 by 24 mesh sieve); 2 hods of chalk lime putty; 3 bushels of fine washed sand.

"This should be treated as trowelled stucco; first well hand-floating the surface, and then well trowelling. A very hard surface is then produced.

"*Selenitic Clay Finish.*—5 pails of water; 1 bushel of prepared selenitic lime; 3 bushels of prepared selenitic clay; 2 bushels of fine washed sand; 1 hod of chalk lime putty.

"This mixture, well hand-floated to a fair face, and then well trowelled, will produce a finished surface equal to Parian or Keene's cement, and will be found suitable for hospital walls, public schools, etc. Being non-absorbent, it is readily washed.

"The use of ground selenitic clay improves the mortar, and renders it more hydraulic.

"When the selenitic clay is used, 2 bushels may be added to 1 bushel of prepared selenitic lime, the proportion of sand, ballast, etc., being the same as for prepared selenitic lime. The use of selenitic clay effects a considerable saving, as it is much cheaper than lime.

"*For outside Plastering* use 6 or 8 bushels only of clean sand, and for finishing rough stucco face use 4 or 5 bushels only of fine washed sand, to the proportions of lime and water given.

"*Plastering on Walls* can be finished by the above processes, as two-coat work in 24 hours, while the ceilings can be floated immediately after the application of the first coat, and be set in 48 hours."

The advantages of this material for plastering are—its cheapness, as it can be used with a very large proportion of sand; its quick setting, which enables the coats to be applied rapidly in succession, and prevents delay.

Selenitic lime or mortar should not be used in conjunction with

gauged stuff for cornices, screeds, etc. No more mortar should be gauged than can be used the same day.

In applying selenitic plaster to quartered partitions or ceilings, care must be taken that the supporting woodwork is thoroughly seasoned, for the plaster is rigid and will be cracked if the timber warps and twists.

Rough-Cast is used as a cheap protection for external walls.

The surface of the wall is first "pricked up" with a layer of "coarse stuff," upon which a coat of similar composition is evenly spread; while this is wet, and as fast as it is done in small portions, rough-cast (p. 179), in a semi-fluid state, is thrown upon it with large trowels from buckets, forming a rough adhering crust, which is at once coloured with lime-wash and ochre.

Depeter consists of a pricked-up coat with small stones pressed in while it is soft, so as to produce a rough surface.

Depretor is the name for plaster finished so as to represent tooled stone.

Surfaces.—*Whitewash* is a mixture of any common white fat lime with water. It is used for common walls and ceilings which have to be whitened frequently, and for sanitary purposes.

Whitening is a mixture of whiting and size, used for whitening ceilings and inside walls. It will not stand the weather.

Colouring for very common work is made by mixing naturally-coloured earths, such as ochres, with whitewash.

Distemper is made with whiting and size. Any colouring matter may be added, being first ground in water and added to the whiting. Sometimes a little alum and soft soap are substituted for the size.

It is used for colouring walls and whitening ceilings; but is not fit for outdoor work, as it will not stand the weather.

Distemper is generally laid on cold, and at about the consistency of trembling jelly.

Not more than two coats are required—the first should be thin, and should contain a double quantity of size.

White lead is sometimes substituted for the whiting to produce a smoother surface; and for outside work boiled oil is sometimes added to ordinary distemper to make it weather better.

Pugging is a coat of coarse stuff about 2 or 3 inches thick laid on boards fixed between the joists of a floor. It is intended to prevent sounds and smells from passing from one room to the other (see Part I.), but is rather apt to lead to decay in the woodwork.

Scagliola is chiefly used for imitation marble pilasters and columns.

For the latter a "cradle" is first formed of wood, lathed over, and "pricked up" with lime and hair mortar.

After this has set and is quite dry it is covered with a floated coat consisting of plaster of Paris mixed with various colouring matters in a solution of glue or isinglass, to give greater solidity and to prevent the plaster of Paris from setting too quickly. When the surface is thoroughly hard, it is rubbed with pumice stone, being kept damp and clean with a wet sponge; it is then rubbed with tripoli and charcoal, then polished with a felt rubber dipped in tripoli and oil, and lastly finished by means of a piece of felt dipped in oil only.

This substance has been to a great extent superseded by the use of Keene's and similar cements. (See Part III.)

Arrises, or sharp corners of plastered walls, require to be of extra strength, or protected in some way from being chipped and injured.

Angle Staves are substantial beads or cylinders of wood plugged to the salient angles of the walls, and splayed so as to receive the plaster on each side. They thus protect the angle of the wall from injury.

Cement Angles are often formed instead of angle staves. The angle of the wall, including a strip of 4 or 6 inches wide on each side, is rendered in cement, and is consequently harder and more able to withstand a blow than if finished in plaster. The corner of the wall or of the cement covering may with advantage be rounded.

Cement Staff Beads or *Quoin-beads* are similar in form to those in wood, described at page 73, and are adopted in order to avoid an arris, and to answer the same purpose as angle staves.

CHAPTER IX.

PAINTING. PAPERHANGING. GLAZING.

THE object of painting is to preserve the more perishable parts of a structure from the effects of the weather, heat, gases, etc.

Woodwork should only be painted when it is thoroughly seasoned; if it is not so, the paint, by confining the sap and moisture, only hastens decay.

In the best buildings the woodwork receives at least four coats of paint, sometimes five or six; but in those of an inferior class two or three coats only are used.

Each coat, as the work approaches completion, should incline more in tint to the final colour.

Materials used in Painting.—Before proceeding farther it is necessary to allude briefly to the materials of which ordinary white lead paint is composed, though the composition and peculiarities of these materials, and other points connected with the subject, will be gone into more fully in Part III.

The paint in ordinary use for protecting woodwork is composed chiefly of white lead, linseed oil, and litharge (or other "driers"); sometimes a little turpentine, and small quantities of other ingredients are added, as hereafter explained.

The part played by each of the principal ingredients is as follows:—

The linseed oil soaks into and fills up the pores of the wood, and there dries into a sort of resin, which keeps out the air, and prevents decay.

The litharge or driers quicken the hardening or drying of the oil.

The white lead gives a body to the paint, and combines with the oil to form a kind of soap.

The spirits of turpentine, or "turps," is used merely to save oil, and to make the paint more liquid, so as to work freely. It evaporates, and plays no part in protecting the wood.

Red lead is generally used with the priming coat; it dries well and sets hard.

Proportion of Ingredients of Lead Paint.—The exact proportions

for the different materials to be used in lead paint vary according to the quality of the materials, the nature of work to be done, the climate, and other considerations.

The proportions given in the following table must, therefore, be taken only as an approximate guide for inside work when the materials are of good quality:—

Coat.	White Lead.	Red Lead.	Raw Linseed Oil.	Litharge or Patent Driers.	Turps.	Number of Superficial Yards the Paint will cover.
	Lbs.	Ounces.	Pints.	Ounces.	Pints.	
1st Coat or Priming......	10	1	4	2*	0	63
2d Coat	10	0	2½	2*	1½	100
3d, and remaining Coats	10	0	2	2*	2	113

* Or ½ oz. burnt white vitriol, and ½ oz. litharge.

The last two coats have the final colouring added in proportion to the depth of tint required; from 1 to 2 oz. of colouring matter is added for every 10 yards of surface to be painted, and the quantity of white lead is reduced in proportion.

Painting Woodwork.—*Preparation of Woodwork.*—Woodwork should be thoroughly dry before being painted. The surface should be planed clean and smooth, and free from dust. All nails should be punched in, so that their heads are driven below the surface.

Killing Knots.—The knots should then be "killed" by painting them over with "size knotting" or "patent knotting" (see Part III.) This is necessary, especially with fir and resinous woods, to prevent the turpentine in the knots from exuding through the paint.

There are several other ways of killing knots. Sometimes they are covered with fresh-slaked hot lime for about 24 hours, which is then scraped off; after which they are painted with size knotting, and if this does not kill them they are coated with red and white lead in linseed oil, and when quite dry rubbed smooth with pumice-stone.

Sometimes, after application of the lime, they are ironed with a hot iron, and then painted smooth.

In superior work the knots are cut out to a slight depth, and the holes filled up with putty made of white lead, japan, and turpentine.

Sometimes the knots are covered with gold or silver leaf.

INSIDE WORK.—*Priming.*—After "knotting" the "priming" coat is laid on. This generally contains a large proportion of red lead, which makes it set harder, and gives it the pink colour familiar to all in new work.

The object of this coat is to fill the pores of the wood before applying the colouring coats, which would otherwise be sucked up and wasted by the wood.

"Painters will sometimes for cheapness prime with clearcole or glue size instead of oil, which form a skin over the surface, without entering into the pores of the wood; it is liable to peel off, and should never be allowed unless the surface is too greasy or dirty to take oil priming."[1]

Stopping.—The surface should now be well rubbed down with fine sand-paper or pumice-stone, and all holes and cracks stopped with putty.

Second Coat.—When the priming is dry the second coat is laid on and allowed to harden. If the knots still show, they may be covered with silver leaf, gummed on with size. This, however, is seldom done in practice.

Third and Fourth Coats.—The third coat is then applied, and when it is dry and well rubbed down the finishing coat is added.

In good work each coat should be carefully rubbed down with sand-paper or pumice-stone, and well dusted, before the next coat is laid on.

Flatting.—For delicate interior work a fifth coat may be added, mixed with turpentine only, and containing no oil. This causes it to dry with an uniform flat dead surface, without gloss.

This coat must be laid on quickly, of a tint somewhat lighter than the ground colour.

It does not protect the material to which it is applied, as an ordinary coat of paint would do, for the turpentine evaporates, leaving only the pigment.

Flatted work will not last when exposed to the weather, nor will it, as a rule, stand washing; if it is required to do so, a little copal varnish must be added to it when mixing.

"Sometimes a little size, or raw oil well bleached, is added to the turps, in order to enable the paint to stand washing better, in which case it is called *bastard flatting*."[1]

OUTSIDE WORK.—If the paint is to be exposed to the sun

[2] Seddon's *Builders' Work.*

boiled oil should be used, and the quantity of turps in the second coat should be reduced to about one-half that mentioned on page 195, and there should be no turps used in the remaining coats, except in winter, when a little is necessary to make the paint work freely.

Varnishing.—Varnish may be applied either to painted surfaces, or to the original surface of the wood; in the latter case it may either be plain, or stained with tints to darken the grain, or to imitate the colour of different woods.

"Varnish adds greatly to the appearance and durability of paint, but at the same time shows up the defects of broken or uneven surfaces.

"A priming coat, followed by a dark coat, such as chocolate or purple brown, and finished off with a coat of common varnish, is cheaper than and as durable as four coats of common colour, it looks better, is more rapidly executed, and stands washing well."[1]

New plaster work should be well sized with a weak solution of glue before being varnished.

Woodwork to be varnished should be very dry. The colour to be used should be ground up and dissolved with the varnish in the preliminary coats; the last coat should contain very little colour—better none at all.

The surface of woodwork should be treated with size before being varnished, to prevent it from swelling. This also fills up the pores, and causes a saving in the quantity of varnish used.

"Walls may be coloured and varnished thus:—First apply at boiling heat two coats of whiting, mixed with strong glue size; then fill up defects with mastic and water, rub smooth with pumice-stone, and cover with two coats of coloured varnish, the first coat mixed with one quarter of the required colour, the last coat with only half as much colour; the colour should be ground very fine, and the varnish should be copal varnish."[1]

Graining.—Four or five ordinary coats of paint having been applied, the last is composed of equal parts of oil and turpentine, and should approximate in tint to the final colour required, after which thin glazings of Terra de Sienna, Umber, Vandyke brown, or other required tints, are applied.

These tints may for ordinary work be ground in water, and mixed with small beer; but for oak graining a thicker substance is required, and the colour is mixed with turpentine and a little

[1] Seddon's *Builders' Work.*

turpentine varnish, and its surface, before it is dry, is scratched over (with *combs*, or with flat brushes, dipped in oil and turps), to imitate the grain of different woods. The representations of knots are produced by dexterous touches with the tips of the fingers, or with pieces of cloth, or sponge, moistened with turps. In ordinary work the surface is completed by covering it with two coats of copal varnish.

The ground and the graining colours differ with each variety of wood to be imitated—thus, for *Light Oak*, the ground would be of white-lead and stone-ochre thinned with half raw oil and half turps; the graining of raw umber and whiting thinned with half and half as above, the overgraining of Vandyke brown in water. For *Bird's-eye Maple* the ground would be of white stained with vermilion, thinned with 3 turps, 1 oil; the graining York brown, Vandyke brown, and burnt sienna, in porter, with a little paste.

A detailed description of the processes by which different kinds of wood are imitated would be of no practical use; the examples just given are merely to convey a general idea of the methods adopted.

Grained work, including the varnishing, lasts longer than ordinary painted work.

Superior work is "*overgrained*"—that is, a glaze of colour in beer, as dark as may be requisite, is laid over the comb-work in shades thrown across the work.

Painting Plaster.—Plaster to be painted should be carefully laid, and its surface free from air bubbles or flaws caused by the "blowing" of the lime.

Special care must be taken that both the plaster and the wall itself are perfectly dry before they are painted.

It is safer to distemper the walls and leave them for two years before painting. Then brush the distemper well down (without washing, unless it is greasy), and paint over it.

There are several methods of applying the paint, all of which are influenced by the very absorbent nature of the plaster.

The plaster may be primed with glue size to prevent absorption, and then four coats of ordinary lead paint applied. Care should be taken that the whole surface stands out with an equal gloss, after which it may be flatted.

The plaster may be primed with two or three coats of boiling linseed oil. When this is dry it is covered with a thin coat of

weak size, tinged with red lead, to stop all absorption, and give the work a uniform appearance, and then finished off with two coats of oil paint, and a flatting coat if required; or with two coats of coloured varnish, as described at page 197.

Another plan is to prime the plaster with white lead and linseed oil containing a little litharge, and mixed to the consistency of cream. When the oil is absorbed into the plaster, and this coat is dry, another similar coat is given. In a few days a third coat may be added, rather thicker, and containing a little turpentine. By this time, the plaster being thoroughly saturated, a fourth coat, thinned with equal parts of turps and oil, may be added, and then the flatting coat; or, when the work is not required to be very durable, the fourth coat may be omitted.

SANDING.—Fine sand is sometimes thrown on to the last coat while it is wet, with a view to imitating the rough surface of stone.

FRESCO is painting on plaster done while it is wet. It requires to be performed with great rapidity, and with care, as the work cannot be altered.

Painting Canvas and Paper.—*Canvas* to be painted should be prepared with size—oil causes it to rot.

Paper should be covered with a thin coat of oil paint, and then the other coats applied as usual.

Sometimes after the first coat of paint a coat of size is applied; but this, though cheaper, is not such good work.

Clearcole consists of white lead ground in water and mixed with size. It is useful in preparing greasy and smoky surfaces to receive paint, which is afterwards laid on in the ordinary way, the white lead being mixed in half oil half turpentine with the colouring pigment and driers, and laid on as stiff as possible.

Repainting Old Work.—The surface should be scoured with soap and water; if greasy or smoky, washed with lime water; when dry, rubbed down with sand-paper or pumice-stone; all necessary repairs should be made, cracks and openings stopped with putty, and portions from which the paint is blistered or knocked off brought up to the general level by painting, or with cement, before the surface is repainted.

When the old paint is very much blistered, it should be removed altogether before repainting.

This may be done by various solutions containing potash, quicklime, etc., which will be described in Part III.; or the old paint may be scraped or burnt off.

Painting Ironwork.—*Cast Iron* should be painted directly it leaves the mould, in order to preserve the hard skin which is formed upon the surface of the metal by the fusing of the sand in which it is cast. After this a second coat will be required, and will generally be sufficient for the preservation of the iron from atmospheric influences.

In any case all rust upon the surface of castings should be carefully removed before the paint is applied.

Wrought Iron.—Before painting wrought iron, care must be taken to remove the scales or film of oxide formed upon the surface of the iron during the process of rolling, and which, by the formation of an almost imperceptible rust, becomes detached from the iron itself.

An attempt to prevent this rusting is sometimes made by dipping the iron while still hot in oil. This plan, however, is expensive, and not very successful.

Paraffin may with advantage be substituted for the oil.

The scale is sometimes got rid of by "pickling," the iron being first dipped in dilute acid to remove the scale, and then washed in pure water.

"If the trouble and expense were not a bar to its general adoption, this is the proper process for preparing wrought iron for paint, and it is exacted occasionally in very strict specifications.

"But somewhat the same results may be obtained by allowing the ironwork to rust, and then scraping the scale off preparatory to painting. If some rust remains upon the iron, the paint should not be applied lightly to it, but, by means of a hard brush, should be mixed with the rust."[1]

Ordinary lead paint may be used for ironwork but it is thought that the lead and iron are apt to set up a galvanic action together, which destroys the paint.

The paints made with oxide of iron (some of which will be described in Part III.) are therefore preferable for this purpose; but they must be used alone, and not laid upon a priming containing lead, or the two metals will set up a galvanic action as above described.

Bituminous paints are said to adhere better than others to the surface of the iron, and to form a plastic film which yields without cracking when the iron expands and contracts under changes of temperature.

[1] Matheson's *Works in Iron.*

All tooled surfaces in ironwork should be coated with tallow and white lead.

Gilding is of two kinds—"*burnished*" bright or left "*dead.*" The latter description is most usual in the decoration of buildings.

The painted surface is covered with "oil gold size." When this is dry but sticky, the gold leaf is laid on in narrow pieces, overlapping slightly at the edges. These are pressed down to the surface with cotton-wool, and the loose portions brushed off.

In gilding varnished work, white of egg beaten up in water is applied to those parts where the leaf is not required to stick.

When woodwork is to be gilt with burnished gold, a different size is used, called "burnished gold size." The leaf adheres to this, and when the size becomes hard the surface of the leaf is rubbed bright with a dog's-tooth or other burnisher.

In gilding ironwork the surface of the iron must be very carefully cleaned, and then painted, first with two coats of oxide paint and then two coats of lead paint of light colour. It is then ready for sizing and gilding.

PAPERHANGING.

Walls to be papered should be thoroughly dry before the paper is hung.

The surfaces of walls to be papered for the first time should be stopped, rubbed smooth with pumice-stone, and then treated with a coat of size, which prevents the plaster from absorbing the paste.

In order to obtain a smooth surface to work upon, a plain coarse white "lining" paper is sometimes hung first. In hanging lining papers the edges of adjacent pieces overlap about $\frac{1}{2}$ inch, and are distempered, and well rubbed down, to prevent their showing through the wall paper. Common papers are hung with their trimmed edges facing the light, so that they may not cast a shadow. Good papers are hung edge to edge.[1] Where the walls are damp, and battening with lath and plaster would be too expensive, canvas may be stretched tight, and nailed to battens, to receive the paper; it is, however, generally unsatisfactory, as it expands and contracts with the changes in the weather.

The heads of the nails securing the canvas should be covered over with strips of common paper before the papering is hung. Iron nails should be painted.

[1] In ceilings the edges of the paper should run at right angles to the principal light in the room.

Re-papering.—In re-papering walls the old paper should be removed, the walls scraped, washed, stopped, and coated with size; or, if the old paper is left on, a coat of size may be applied to it, and then over that a coating of whiting and size or distemper.

There is considerable danger in leaving the old paper upon the walls, and it should never be allowed, as the paste which secures it is apt to become decomposed and injurious to health.

"*Indiarubber, gutta percha, laminated lead, and tinfoil papers* 'have been used as lining papers for walls where damp would be likely to injure the paper; but all these are now superseded by the papers made by the Willesden Waterproof Paper and Canvas Company, 34 Cannon Street, London, which are much cheaper, and may even be used by themselves, being supplied in certain colours besides admitting of being coloured.' The drying of walls may be quickened by rubbing them over with sulphuric acid."[1]

GLAZING.

Glass is fitted into window-sashes made of wood or iron, or into lead work, as described at page 206.

GLAZING IN WOODEN SASHES.—The construction of a wooden sash has been described at page 196, Part I., and it has been there explained that the styles and bars of the sash have rebates formed upon their inner sides to receive the edges of the panes with which they are to be glazed.

The size of the squares, and the stoutness of the sash bars, should be arranged so as to suit the kind of glass intended to be used.

The glass is cut with a diamond into panes. The dimensions of these should be a little less both ways than the distances between the sides of the rebates upon which they are to rest, so that the edges of the glass nowhere actually touch the woodwork of the sash, and any jar received by the latter is deadened by the intervening putty before it is felt by the glass.

Fig. 373.

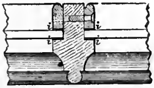


Fig. 374.

A layer of putty is spread over the narrow part of the rebates, upon which the glass is firmly bedded. This is called the *back putty;* as the glass is pressed upon it the superfluous putty is

[1] Seddon's *Builders' Work.*

squeezed out round the edges of the panes, and cut off on the inside.

This superfluous putty should not be cut off for four or five days, as its removal may disturb the front putty.

The back putty is sometimes omitted in inferior work. When plate-glass is used it is not required.

The glass is then *front-puttied,* the rebate is *stopped,* that is filled in with putty to a triangular section, as shown in Fig. 373. This soon hardens, and keeps the glass secure.

Care must be taken that the putty does not project beyond the front of the rebate, so as to be seen from the inside of the window.

Large panes of plate-glass are not back-puttied, for it would be useless in the case of large and heavy panes to attempt to compress the putty when bedding the pane.

In very large and heavy panes copper brads or *sprigs* are driven in to secure the glass more firmly before it is front-puttied, or the glass may be secured by beads or mouldings secured to the bars or frames of the sashes, as in Fig. 374.

Large panes of plate-glass in doors are sometimes bedded in wash-leather or vulcanised indiarubber, one piece glued to the inside of the rebate the other placed on the reverse side of the glass (see *i i,* Fig. 374), so as to deaden the effects of concussion.

Plate-glass is thick, and keeps a room warm, but is expensive, and therefore used only in houses of a superior class.

Firsts, seconds, and thirds sheet, or crown, glass are used in buildings of an inferior description (see Part III.)

The glazing is generally done after the plastering is finished and the floors laid, and before the painting, the sashes being primed however before the glass is put in, in order to prevent the wood from absorbing the oil out of the putty. The surfaces of all puttied joints should be painted, to prevent the oil from evaporating.

Glazing in Iron Sashes.—Iron sashes have bars of similar shape to that of wooden sash-bars, and are glazed in the same way, particular care being taken that the glass does not touch the iron, in order to avoid the risk of its being broken.

Glazing Skylights.—As already mentioned (see p. 97), skylights and other inclined sashes have no horizontal sash-bars; the panes are made to overlap, as shown in Fig. 188. When they are large and heavy, any tendency for them to slip down is prevented by hanging the tail of each on to the head of the pane

below by means of a zinc or copper *tingle*, as shown by the dark line in Fig. 188.

"Considerable overlap is necessary to prevent leakage, for the overlapping surfaces can seldom be brought into direct contact; consequently wet is held and drawn up by capillary attraction, and if the lap is not sufficient it will drip over the heads of the under sheets, and, moreover, get blown up by the wind; therefore it is better, if possible, to keep the overlapping surface far enough apart to prevent any capillary action coming into play. The tails of the panes are frequently cut to a point or rounded to throw the water off better, as well as to turn it away from the sash-bars."[1]

Glazing without Putty.

In large roofs, especially those which are subject to vibration, as in the case of railway stations, or those subject to hot fumes such as arise from some workshops, it is desirable to avoid the use of putty, which becomes dried and loose, and is shaken out so that leaks are caused in the roof.

Every good system of glazing without putty should have the following characteristics.

a. It should be simple in construction, so as to be easily repaired by ordinary workmen. Broken panes should be easily replaced.

b. It should allow of expansion and contraction of the roof (if it is of iron) under changes of temperature without breaking the glass.

c. It should be of such a structure and strength that men can easily get at any part of it for cleaning and repairs.

d. The fastenings and metal parts should be so placed as to be protected from corrosion by the weather.

e. It should not be obscured by heavy framing or sash bars, but should give a good proportion of light for the area it covers.

Of late years many systems of glazing have been introduced in which the use of putty is altogether avoided.

Of those now in use the principal forms are shown in Plate XIII. The writer has had most of these forms tried. He prefers, however, not to make any invidious comparison between them. Sometimes a system not suitable for one structure is suitable for another.

[1] Seddon's *Builders' Work.*

SYSTEMS FOR GLAZING WITHOUT PUTTY.

Plate. XIII.

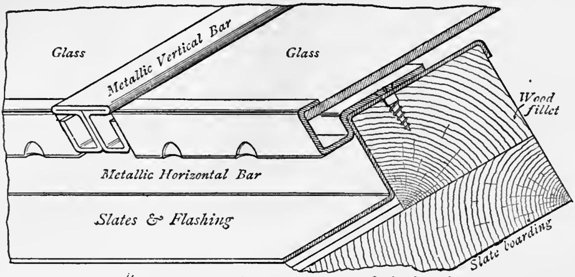
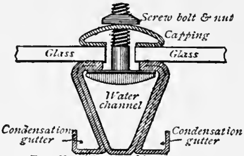


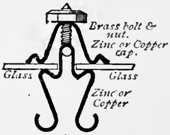
FIG. 375. *Rendle's "Acme" System for squares up to 4ft. in length.*

FIG. 376.



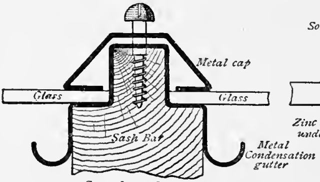
Rendle's "Invincible" System for squares up to 8ft. in length.

FIG. 377.



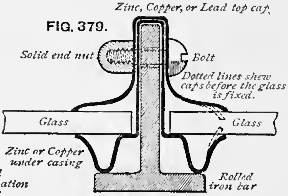
Helliwell's "Perfection" Bar.

FIG. 378.



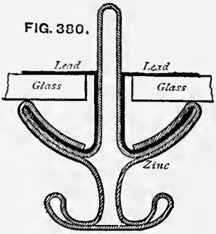
Causeley's System.

FIG. 379.



Shelley's "Unique" System.

FIG. 380.



Pennycook's System.

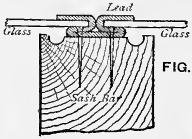


FIG. 381.

Grover's System.

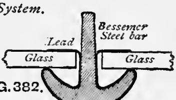


FIG. 382.

British Patent Glazing Company's System.

The student can test these forms, and many others that he will see advertised from time to time, by the list of characteristics given above, and can thus form an opinion as to which is best suited for a particular purpose.

Lead Work.

The small diamond-shaped panes used in old cottages and in churches are set in lead strips called *cames*, soldered together to form the panes.

The lead is first cast into bars, and then passed through a vice, which turns them out in cames about 6 feet long.

The section of the cames resembles the letter H. The dimensions vary according to the purpose for which the lead is intended. In the size most commonly used the sides of the H are $\frac{3}{8}$ inch long, the cross-bar between the sides $\frac{3}{16}$ inch long, and the thickness of the metal about $\frac{1}{48}$ inch.

The sides of the cames are bent down so as to admit the panes, and then turned up again, so as to form a groove in which the edges of the panes are secured.

In large windows the leadwork is strengthened by iron *saddle-bars*, to which the cames are secured either by leaden *bands* or with copper wire soldered to the cames and twisted round the iron. The saddle-bars themselves are supported, when necessary, by iron *stay-bars*, or *standards*, which are fixed in the masonry.

FRETWORK is somewhat similar to the leadwork just described, but that the cames are of much lighter section, and instead of being in regular shapes, such as squares and diamonds, the pieces of glass are cut so as to form figures or other patterns, and the cames are bent round to fit the edges of the pieces.

Chapter X.

EXCAVATIONS, SHORING, SCAFFOLDING.

EXCAVATION.

IN clearing and levelling the site for buildings very large quantities of earth may have to be removed from one spot to another, for which special arrangements would be necessary. Such arrangements, however, are rather beyond the province of these Notes, in which it is proposed to consider only the excavations required for the foundations of buildings to be placed upon a site which requires no special preparation in the way of levelling.

In all excavations for foundations the solid ground at the bottom of the trenches should be left to the required levels—not made up with loose earth—and temporary drains should be cut to carry off the rain that may fall during the progress of the work.

In excavating trenches for brick or stone footings an extra width of about 6 inches on each side is generally allowed at the bottom of the trench to give the men room to build; but, when concrete is to be used the excavations should be of the exact width required for the bed of concrete itself.

SHORING AND STRUTTING.

When trenches have to be dug in loose ground it is necessary to support the sides of the excavation by timbering and shoring.

In moderately firm ground, after a depth of 3 or 4 feet has been excavated, a few rough planks or "*poling boards*" P P (Fig. 383) are placed at intervals varying with the nature of the soil against the sides of the trench, and kept up by jamming or wedging in between them struts (S) of rough scantling from 4 to 6 inches square.

In looser ground it is necessary to place the poling boards

closer together, and so support them (Fig. 384) by 3-inch planks W W called "walings." The struts must be made thick, in pro-

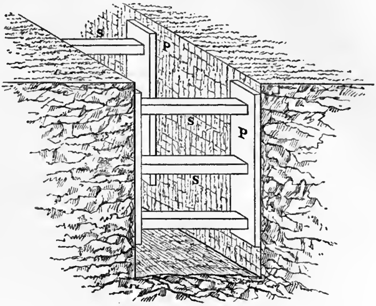


Fig. 383.

portion to the width of the trench and the pressure upon them, and their distance apart will depend upon the strength of the walings and the nature of the soil.

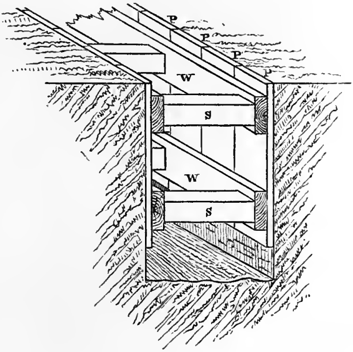


Fig. 384.

The poling boards P P are often in short lengths of about 3 feet, so that no greater depth has to be excavated before they can be inserted.

In very loose soils, such as running sands or slipping clays, it is evident that the sides would fall in if an attempt was made

to excavate the trenches to a depth of 3 or 4 feet before supporting them (Fig. 385).

To prevent this the poling boards are sometimes put in horizontally—as "*sheeting*"—one at a time. A portion 9 inches or a foot deep is excavated, and at once supported by planks placed longitudinally on both sides and kept apart by struts, then another depth of 9 inches is taken out and another plank placed on each side below those already in position, and these last also strutted. When five or six planks have been thus inserted on each side walings may be added, and some of the struts dispensed with.

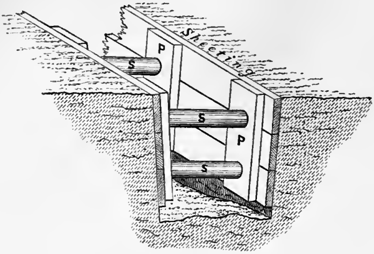


Fig. 385.

The timber used for shoring important excavations should be hard and tough—seasoned,—barked before use—so placed as to receive the stress on its end grain, and as large a bearing surface as possible should be allowed, especially when the end of one timber bears upon the side of another.

All shores should be driven from above, not sideways or horizontally. The planks or walings at the sides of an excavation should be at a slight inclination, as in Fig. 385, the upper edge sloping toward the earth they support, so that when the shore, whose ends are cut to the proper angle, is driven down from above, it will take a fair bearing.[1]

Fig. 385 shows round shores, which are sometimes made by cutting up old fir scaffold-poles. Half-round walings are also often used.

Sometimes in very bad soil long planks called "runners," having sharp ends shod with iron, are substituted for the poling boards; these are driven in as the trench is dug, their points being kept a foot or so below the bottom of the portion excavated.

In very deep excavations platforms are required at vertical intervals of about 5 feet to receive the earth thrown up by the men from stage to stage.

[1] *Transactions*, Society of Engineers, 1873.

In this case these stages may rest upon the struts of the timbering, which should be made particularly firm to ensure safety

Shoring Buildings.

It is frequently necessary to afford buildings temporary support in consequence of the instability of the walling, caused either by the removal of adjacent houses, by faults in construction, or by defective foundations.

Inclined Shores.—This support is obtained by propping up such walls as are likely to be unstable with balks of timber called "shores."

Shores may be used singly, as shown at A, Fig. 386, or arranged in groups of two or three, according to the height of the wall to be supported.

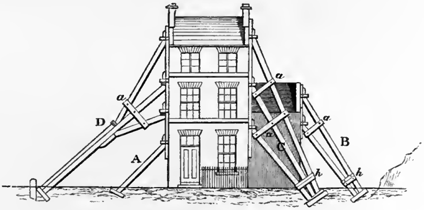


Fig. 386.

The arrangement at B is a double shore adapted for walls of moderate height. Three shores are used at C, where the wall is higher.

Another combination of those shores, shown at D, is adapted for cases in which long timbers are scarce.

In all these cases the shores are placed in an inclined position, their feet are fixed firmly on the ground—or, if that be soft, are made to abut on blocks or thick planks called "footing pieces," buried in the ground; these distribute the pressure, and prevent the shore from being forced into the soil.

When two or three shores are combined they are secured together by means of cross pieces of plank, *a a*, nailed on each side of the balks; the feet are strongly bound together with hoop iron, *h h*.

The upper end of the shore abuts against a thick plank placed

against the wall extending over the height required to be supported, and secured as follows (see Fig. 387):—

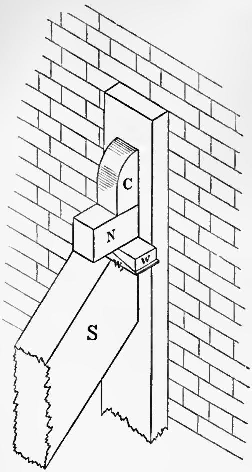


Fig. 387.

Holes from 4 to 6 inches square are cut through the plank and into the wall behind it; through these are passed pieces of scantling, N, called "needles," which, being about a foot long, enter the wall some 4 or 5 inches and project about the same distance from the outside of the plank, thus forming an abutment on the top of the shore S, wedges, *w w*, being inserted so as to make up for any opening or inequality in the joint. Wooden cleats, C, are generally nailed above the needles so as to give them additional strength.

Horizontal Shores.—In cases where one or two houses are taken out of a row the external party walls of those remaining are supported by horizontal shores of different forms, such as those shown in Fig. 388.

If the opening be narrow and the height to be supported moderate, as at A, Fig. 388, the shore may consist simply of a horizontal balk connected with struts abutting against planks, which serve to distribute the support over a greater height of wall, and may be secured to it by needles as above described.

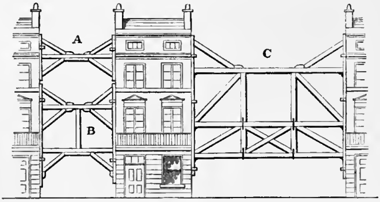


Fig. 388.

When the walling to be supported is higher, a combination of two such shores may be made, as shown at B, Fig. 388.

If the opening be of considerable extent the shoring may be of a more elaborate character, forming deep trusses, as at C, Fig. 388, placed at intervals of a few feet throughout the depth of the buildings.

When a passage is formed between two houses and they

have to be strutted apart permanently, the shores may be of iron, such as old rails, bent and secured in a form similar to A, Fig. 388.

SCAFFOLDING.

Scaffolds are temporary erections of timber supporting platforms close to the work, on which the workmen stand and deposit their materials.

Bricklayers' Scaffolds.—When a wall is built as high from the ground as the bricklayer can conveniently reach he commences a scaffold by planting a row of poles or "standards," S S, about 10 or 12 feet apart (Fig. 389).

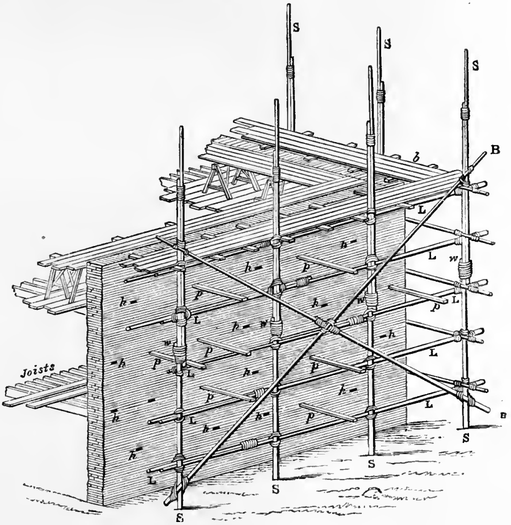


Fig. 389.

Across these standards, at the level of the work already done, are poles, called "*ledgers*," secured with lashings which are in many cases tightened up by wooden keys or wedges, and upon these are laid short transverse pieces called "*putlogs*," *p*, about 6 feet long and 3 inches thick, which form bearers to support the scaffold-boards, *b*.

The putlogs are from 4 to 6 feet apart, according to the strength of the scaffold-boards, which should be about $1\frac{1}{2}$ inch thick; header bricks are temporarily left out, forming holes, *h h*, into which one end of each putlog is inserted, the other end resting upon the ledger.

Three or four scaffold-boards are laid across the putlogs; on these the bricklayer stands and his materials are deposited.

The materials are either carried up ladders in hods, or hoisted by means of a pulley or windlass and rope.

In many cases a platform for landing materials is erected in the same way as the scaffold, and close to it.

When the wall is so high that it can barely be reached from the scaffold-boards another row of ledgers is lashed to the standards, fresh putlogs laid, and the scaffold-boards are raised to the new level.

The ledgers and putlogs used at the lower levels are left in position to steady the scaffold, and if the building be very high and in an exposed situation the scaffolding must be stiffened by lashing long poles, called "braces," B B, diagonally across the outside of the standards and ledgers.

Care must be taken not to load a scaffold too heavily, otherwise the putlogs will injure the green work upon which they rest.

The scaffold for the inside of the brick or rubble walls of buildings sometimes consists merely of planks laid across the joists of the different floors, which are placed in position for the purpose; when the walling has risen more than 5 feet above a floor a fresh tier of planks is provided, supported on trestles, empty casks, or anything that may be available.

When there are no floors on the inside of the wall the scaffold then is constructed in the same way as for the outside.

Masons' Scaffolds.—Scaffolding for ashlar walls, of which the stones can be lifted without machinery, are formed with standards and ledgers; but as putlogs cannot conveniently be inserted in the face of the masonry, a row of standards is used on *both* sides of the wall, between which the putlogs are lashed, so that the scaffolding is entirely independent of the building.

Building without Scaffolds.—In some parts of the country houses many stories in height are erected without scaffolds at all, the work being all done from the inside, and the men supported only by temporary platforms formed on the different floors in succession.

Special Scaffolds.—*Scaffolds made from square scantling* have been used under the supposition that the timber might eventually be used in the building, that cords would be saved, and that the scaffolding could be more quickly erected and taken down.

Practically, however, these advantages have not been found to exist, and, where the scaffolding is high, iron sockets for uniting the lengths of scantling and other expensive and awkward contrivances have been found necessary, so that the system may be considered a failure.

Gabers Scaffolds, made from pieces of flat timber or deals bolted

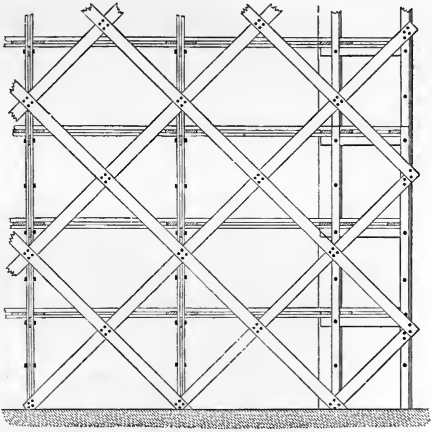


Fig. 390.

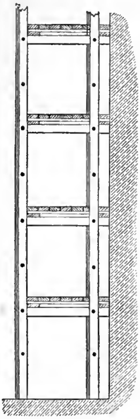


Fig. 391.

together and well cross-braced, are sometimes used in Scotland. Their general construction will be understood from Figs. 390, 391, which are taken from an actual example.

Gantries.—When the stones to be lifted are very heavy, scaffolds of poles lashed with cords would not be safe, nor could they carry the necessary machinery for lifting the stones.

In such a case a staging or "gantry" is erected of balk timber, supporting a tramway, upon which runs a "traveller," extending across the gantry at right angles to the direction of its length, and consisting of a stage on wheels, along which moves a truck carrying a double purchase crab.

As the stage or traveller can move anywhere in the direction

of the length of the scaffold, and the truck can move along the traveller across the width of the gantry, it is evident that the crab can be brought vertically over any point lying within the scaffolding.

The traveller consists of two trussed beams (see Part I.) fixed parallel to one another, and about 4 or 5 feet apart.

At each end the beams are united by a cast-iron carriage containing a pair of wheels, which run along the rails fixed upon the upper beams or sills of the gantry.

The traveller is worked along by turning these wheels, which is effected by machinery worked either from the platform carrying the crab, or by men stationed at the ends of the traveller.

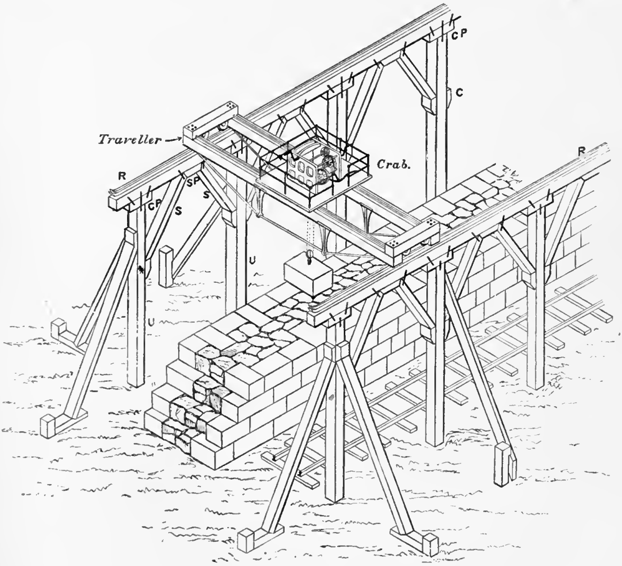


Fig. 392.

The truck carrying the crab is moved along on the rails of the traveller, across the gantry, by machinery on its own platform.

The outer wheels of travellers moving on a circular gantry are made with very broad tires, so that they may not jam upon the rail.

Fig. 392 is a longitudinal view of a gantry constructed of balk timbers. The uprights, U U, are placed from 10 to 20 feet apart according to the size of timber available, and the capsills or "runners," R R, are supported by struts, S S, which butt against a straining piece, SP, and rest upon cleats, C. Corbel pieces are often introduced, as shown at CP.

The standards or uprights at the end of the gantry should be strutted as shown, and so should every standard be supported by struts on the outside to prevent lateral movement.

In order to keep the timber as perfect as possible bolts should be avoided, and the balks united by straps or "dogs."

The latter are pieces of iron about $\frac{3}{4}$ inch square, the ends of which are turned down and pointed by being splayed on the *inside* so as to draw the timbers together when driven home.

It frequently happens that a line of railway can be brought from the stoneyard right under the gantry, as shown, in which case the stone can be lifted off the trucks by the traveller and set at once.

Derrick Cranes of the form shown in Fig. 393 are sometimes used for lifting the materials required in building large houses, as well as other structures.

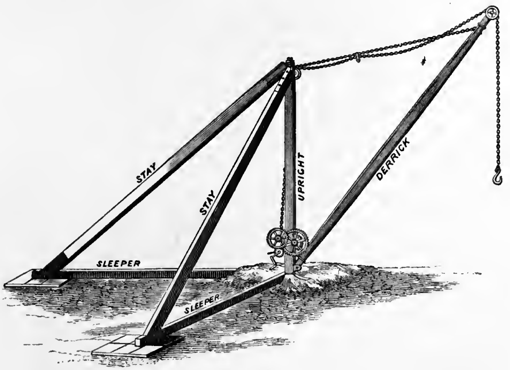


Fig. 393.

The crane is placed on a platform in a high and central position, so that it can reach the stones or other materials where they are deposited, and also by revolving the jib or derrick place them where they are required in the work. The derrick can be raised

or lowered as well as revolved; this enables the length of its reach to be varied so that materials can be picked up or set down on any spot within its range.

Methods of securing stones to be lifted.—It is manifestly of the utmost importance that stones to be hoisted should be simply and safely secured to the chain or "fall" by which they are to be lifted.

There are several ways of doing this:—

1. *Chain.*—Rough stones may merely have a chain passed round them; this, however, would injure worked stones, and would be inconvenient while they were being set.

2. *Lewis in separate pieces.*—A hole is cut in the stone, being wider at the bottom than above (see Fig. 394); into it are fitted three pieces of iron of the shape shown; the two side pieces are first placed, then the centre piece, and the three are united by a bolt passing through them. This bolt also secures a ring or shackle, into which the hook of the fall is inserted when the stone is to be raised; as the stone rises, the lewis, in virtue of its wedge shape, becomes tightly jammed into the hole.

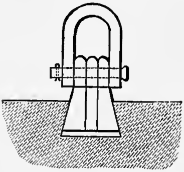


Fig. 394.

3. *Lewis in one piece.*—An improvement on the ordinary lewis, frequently used, is shown in Fig. 395.

In this the chain is attached to a ring passing through the eye (*e*) of the centre piece, *c*, the lower part of which is wedge-shaped.

The side pieces are connected to one another by cross pieces, *cp*, of flat iron on each side of the centre bar; they are hinged to the ends of the cross pieces, and with it are free to move up and down the centre piece.

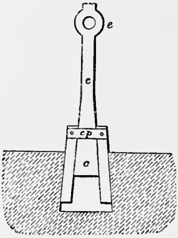


Fig. 395.

When the stress comes upon the lewis the centre piece is drawn up, and as the broader part of its wedge rises between the side pieces it forces them out upon the sides of the hole, and the greater the strain the tighter becomes the grip of the lewis.

When the stone has been lifted a smart tap on the head of the centre piece drives it downwards, the side pieces collapse, and the lewis can be withdrawn.

A great advantage in this lewis is that the pieces are all connected, which saves time, and prevents their being lost.

4. *Lewis for subaqueous work.*—A modification of the lewis (shown in Fig. 396) is used for setting under water. A line is attached to the rectangular piece, after the stone is set this is pulled out, and then the wedge piece can easily be removed.

5. The following is a substitute for the lewis sometimes used for hard stone. Two short bars connected by a chain are let into holes inclined inwards towards the centre of the stone; when the strain comes upon the centre of the chain the bars are pressed inwards and grip the stone.

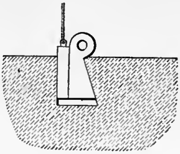


Fig. 396.

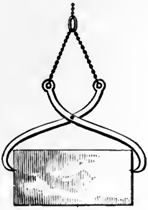


Fig. 397.

6. *Nippers.*—A pair of nippers is sometimes used thus (Fig. 397):—

A small piece is picked out on each side of the stone so as to give the point of the nippers a hold.

The upper ends or "eyes" of the nippers are fixed to a short chain which passes through a ring attached to the fall. When the weight comes upon this chain its effect is to draw the eyes of the nippers inwards, which has a similar effect upon the points and tightens their hold upon the stone.

Care must be taken that these holes in the side of the stone are made so far from the top that the weight will not cause the points to drag up through the stone.

They should of course be so high that the centre of gravity of the stone is below the points, in order that it may not turn over in the nippers.

In all cases where worked stones have to be lifted by nippers care should be taken in working them to leave little projecting knobs to receive the points of the nippers so that the worked face may not be injured. These little knobs can be dressed off when or just before the stone is set.

CHAPTER XI.

FOUNDATIONS.

GENERAL REMARKS.—In this course the foundations likely to be required for ordinary buildings will alone be described, foundations under water, cofferdams, caissons, etc., being excluded, as appertaining more to engineering works than to ordinary building construction.

The great importance of a stable foundation will be apparent to every one, and need not be dilated upon.

Characteristics of a Good Foundation.—A good foundation should fulfil the following conditions:—

1. It must either be incompressible, or at least equally yielding throughout.
2. It should be perpendicular to the pressure upon it.
3. It should be of sufficient area to bear that pressure.
4. It should be unalterable in nature, either by atmospheric or other influences that it can possibly be subjected to.

Some natural soils fulfil these conditions, requiring only to be excavated to the proper levels; in other soils artificial means must be adopted in order to form a stable foundation.

Classification.—This has led to the classification of foundations under two general heads:—Natural Foundations, and Artificial Foundations.

The different kinds of soils have been arranged as follows[1]:—

1. *Incompressible soils*, such as rock, stony earth, and hard clay, which yields only to the pick or to blasting.
2. *Soils that are incompressible but require to be laterally confined to prevent them from spreading*, such as loose gravel and sand.
3. *Compressible soils*, such as ordinary clay, common earth, and marshy soils, some of which, such as clay and earth, are only compressible to a certain extent, while others are in an almost fluid state.

[1] Mahan's *Civil Engineering.*

Before proceeding to consider these in detail a few remarks may be made which are applicable to all foundations.

Preliminary Operations.—Before commencing a building, trial pits should be dug or borings made at different points on the site, in order to ascertain the nature of the ground, the thickness and inclination or "dip" of the strata; to find out whether water exists, and if so, at what level; also whether the ground has been mined or is full of dangerous fissures. If there be any springs on the site, their source should be ascertained and the water diverted.

The description of foundation having been decided upon, trenches must be dug to the widths and depths necessary, the bottoms of these carefully examined, sounded with a crowbar to ascertain any local defects, and then levelled throughout, in one plane if convenient, if not, in horizontal "benches" or terraces.

"Punning" or ramming the ground before commencing to build will sometimes produce a very considerable compression, and prevent a corresponding sinking of the building.

The ground should be well drained before digging the foundation, to increase its firmness; all bad parts should be cut out and made good with concrete, and loose portions rammed.

Surface water must be carried off by a catchwater drain, and "grips" or small trenches must be formed to carry off all water that may collect in the foundation during its formation.

As fast as walls are built up they should be "punned" (that is, filled in and rammed) on each side.

On benched foundations care must be taken in rising from the lower to the higher level (A to B, Fig. 398) to have large stones with well-dressed beds and the joints as few and as thin as possible, otherwise the unequal settlement caused by the number of joints in A C being greater than that in E F will lead to fracture.

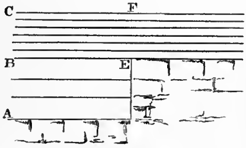


Fig. 398.

In such a case the masonry should be left thoroughly to set before being built upon.

The foundations of the angles of a building should be laid with large and heavy stones, and great care should be taken that the foundations under the higher walls are not liable to consolidate more than those under the lower walls, otherwise where these are connected fractures will appear.

All foundations should be at such a depth as to be out of danger from the effects of frost.

In England a depth of 3 feet will generally be sufficient to ensure this, but in clay soils a depth of 4 feet will be necessary, as they are frequently laid open to injury by fissures formed by heat.

Permanent drains should be laid so as to keep all foundations constantly dry; water is their great enemy, causing swelling, removal and subsidence of the soil, expansion from frost, perpetual damp, etc.—even in some kinds of rock it percolates between the masses and loosens them, so that when pressure comes upon them they sink.

Incompressible Soils.—ROCK.—Solid rock under the *whole* of the building affords a first-rate foundation if it is perfectly uniform in character, thick enough to bear the weight safely, with an upper bed approximately horizontal or perpendicular to the pressure upon it, and not liable to be affected by atmospheric influences.

In such a case it will be necessary only to break down projecting points, cut away loose and rotten parts, making good and carefully filling in all cavities with concrete.

If the strata are inclined there is danger of the upper layers sliding over the lower, and also expense in "benching" or levelling in steps.

Again, if the rock is (like some clay slates, for example) of a nature to disintegrate when exposed to the weather, it should be protected by a bed of concrete.

The foundation should be so arranged that the pressure upon the rock does not exceed one-eighth of that necessary to crush it.

PARTLY HARD AND PARTLY SOFT GROUND.—A foundation consisting partly of rock and partly of some softer stratum is most dangerous and untrustworthy, as the latter will yield more than the former, causing unequal settlement and fracture of the superstructure.

If the softer parts are of small extent they may be arched over, using the adjacent portions of rock as abutments.

If this be not possible they should be consolidated by driving in piles close together (see page 226), or excavating to a good depth and filling in with concrete.

If neither of these expedients can be adopted the building over the soft parts should first be carried up and allowed to settle to

its bearings, and then the remainder built upon the hard rock, the latter being kept distinct from the former.

Gravel, when sound, makes one of the best possible foundations, as it is incompressible, and not affected by atmospheric influences.

If loose and coarse it may be greatly improved by grouting it with thin mortar, or sometimes a thin layer of concrete is spread on the bottom of the trench.

If very unsound it may be necessary to proceed as in the case of loose sand (see below).

Chalk varies immensely in its nature and characteristics; sometimes it is found as hard as rock, in other cases as soft as butter.

The hardest description of chalk may be treated as rock if its permanent dryness can be ensured.

The softness of chalk is caused by wet; before using it as a foundation all water should be removed and prevented from recurring.

This may be done by draining the trench, punning the sides with clay to prevent the ingress of water, or by putting in concrete at weak points.

Springs should, however, rather be diverted than dammed out, as otherwise they will very likely burst through in rainy weather.

Clay is a good soil to build upon when it is sound, tolerably dry, and protected from the action of the atmosphere by making the foundations deep or covering the bottom of the trenches with concrete.

Clay is very liable, especially in hot weather, to crack and form deep fissures, by which water is led below the surface, which will injure the footings unless they are placed deep enough to be out of the reach of the fissures and well drained.

When these precautions are neglected the clay undergoes continual changes in bulk from atmospheric influence, and becomes a very dangerous material to build upon.

Soils requiring Lateral Confinement.—Sand forms a capital foundation to build upon as long as it is prevented from escaping laterally by sheet piling (see page 226) or other means.

Quicksand and Silt.—The same remark applies to these, which are the most treacherous of all soils, and will, unless such precautions are taken, yield or slip under the slightest weight.

In these soils, as also in very loose gravel, care must be taken

to exclude water, which might otherwise penetrate and wash away the soil, causing hollows in the foundation and subsidence in the superstructure.

Compressible Soils.—Foundations in these soils require great care, more especially if the site is made up of different kinds, one more compressible than the other; in such a case unequal settlement may be apprehended, and should be guarded against.

ORDINARY EARTH OR SOFT CLAY.—In these it will be sufficient to dig a trench considerably wider than the thickness of the wall and deep enough to be below the action of frost, and to fill it with concrete.

The pressure is thus distributed by the concrete bed over a larger area, and does not bear so heavily on each superficial foot of the soil.

VERY SOFT SOILS.—When the ground is marshy or of such a nature that it would not bear the weight required, even when distributed over a large area of concrete, more complicated arrangements must be adopted, according to the nature of the case.

1. *A soft stratum of moderate depth overlying hard ground.*

In this case the foundation should be carried down to the solid ground; or, if this would be too expensive, a number of piers may be sunk, and arches turned from one to the other, upon which the building may rest, or similar piers may be used to support a timber platform; or again, instead of the piers, holes may be driven through the soft upper stratum and filled in with concrete, sand (if the ground will resist its lateral pressure), stones, or other incompressible material; or lastly, piles may be driven into the hard substratum to act as supports for a platform.

2. *Ground very soft to an indefinite depth.*

Such ground may be treated in several different ways.

Sometimes a wide trench filled with good concrete, of such a thickness as to resist fracture, will answer by distributing the pressure over such a large area that the soil is enabled to bear it, or a trench may be filled with moist sand carefully punned; in this case the natural soil must be able to retain the sand laterally, as it will press upon the sides as well as the bottom of the trench.

If the trench cannot be kept free from water, holes about 6 feet deep and 6 inches in diameter may be bored and filled with slightly moistened sand. These are better than timber piles, as the sand transmits the pressure upon it tolerably well, and driving is avoided, which shakes the ground.

Another plan is to form a raft of timber or fascines, which floats upon the nearly liquid soil and distributes the weight of the building over a large area.

In such a case it is important that the centre of gravity of the building should be immediately over that of the platform, and the latter should be evenly weighted, or it may sink more on one side than on the other.

A timber platform is constructed by placing short lengths of timber across the foundations; these are tied longitudinally by long planks laid to the width of the bottom course of masonry.

A fascine platform consists simply of two or three courses formed of fascines (long bundles of brushwood) laid close together, the alternate courses being in opposite directions, and the whole being kept in position by wooden pickets.

Such platforms should either be at a depth where they will be constantly wet, or be so drained as to be permanently dry, otherwise the material will soon perish.

Again, a soft soil may be consolidated by driving into it, over an area larger than the proposed building, short piles quite close together; these are prevented from sinking by the friction of their sides against the soil.

On the heads of these piles may be formed a platform consisting either of timber, a bed of clay, or a layer of concrete.

In all these cases the pressure has a tendency to cause the ground immediately around the foundations to rise; this must be counteracted by placing stones or concrete upon it so as to act as a counterbalancing weight.

Sometimes before laying the platform the site is surrounded by sheet piling to prevent the lateral escape of the soft soil when the weight of the building comes upon it.

3. *A crust of good ground overlying a soft substratum.*

If the crust be thick enough to bear the weight required it should be left alone, care being taken not to cut or injure it.

In alluvial soils there is frequently a layer of clay over a stratum of soft mud; in such a case piles would do harm, as they would disturb and injure the crust of clay; it would be better, therefore, merely to pun and consolidate the clay with a rammer.

The upper crust should be sounded by striking it with a log; experience will tell whether it gives out a clear ring or a hollow sound; in the latter case it is not to be trusted.

When the upper crust is not thick enough to bear the weight originally intended, the area of the foundations may sometimes be increased so as to reduce the pressure, on each superficial foot, to what the crust can bear.

When the substratum is sand it will be safe to build upon if its lateral escape is prevented. A peaty substratum should, if possible, be thoroughly drained.

When the hard crust rests upon a soft stratum which crops out on a cliff or the bank of a river, particular care must be taken or it will be found to ooze out and cause a subsidence of the crust.

When the soft substratum is very shallow, open drains may be cut so as to encourage it to ooze out and permit the weighted crust to take its bearings; but if it be of considerable depth such excavations must be carefully avoided.

Concrete Foundations.—The composition, characteristics, and method of making and laying concrete are given in Part III.

The great use of concrete for foundations is generally to form a solid base or platform, which will cause the weight of the building to be distributed over a larger area, and thus reduce the pressure on each superficial foot to whatever the soil is able to bear.

To ensure the stability of the bed of concrete itself it must be composed of such materials, and be of such a thickness, that in case of the subsoil yielding it will settle uniformly in one mass, and bear the cross strain upon it without breaking; care should also be taken that its composition is such that it is in no danger of crushing under the weight brought upon it.

The various cases in which concrete is useful have been considered in the preceding sections.

Piles and Pile Foundations.—TIMBER PILES may be made of elm, larch, fir, beech, oak, teak, or greenheart.

The straightest-grained timber should be selected, the bark removed, and any rough projections smoothed off; all large knots should be avoided, and diagonal knots especially are a source of danger, as a pile is very likely to be broken off at the point where they occur.

Piles should, if possible, be of whole timbers, and driven with the butt, or natural lower end, downwards.

The head of the pile should be bound round with a wrought-iron hoop to prevent it splitting when driven.

The lower end should be pointed, and if it has to encounter stony or hard ground should be shod with iron.

Fig. 399 shows an ordinary form of wrought-iron shoe, and Fig. 400 an improved form, in which the lower portion C is of cast-iron, forming a good wide abutment for the timber, which tends to prevent the danger of its being crushed as the pile is driven. The wrought-iron pins, *a a*, are cast into the portion C, and their heads hammered out like a rivet to secure the straps *s s*.

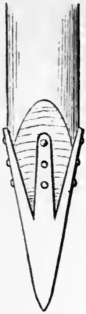


Fig. 399.

Fig. 400.

From the remarks at page 223 it will be seen that piles are used for foundations in three different ways. They receive distinctive names, and their forms and dimensions are governed accordingly.

Bearing Piles are driven down either until they reach a hard stratum, or until the friction on their sides prevents them from sinking, upon which they are used as pillars to support a platform of timber.

Such piles, if of wood, should be whole timbers from 9 to 18 inches in diameter, and if they are in soft soil their length should never be more than about twenty times their diameter, or there will be danger of their bending when driven.

Short Piles are driven into soft soil to compress and consolidate it. Upon their heads may be placed a platform of timber or layer of clay or concrete.

These piles are only from 6 to 12 feet long—of round timber about 6 inches in diameter. They should be driven as close together as is possible without the driving of one pile causing the others to rise; to prevent this, it is found necessary to place them at intervals of about 2 feet 6 inches from centre to centre.

Sheeting Piles are used to enclose the areas of a foundation, and thus prevent the soil from spreading laterally, or to protect it from the action of water.

Sheet piles are flat planks, varying in width, and from 3 to 10 inches thick. They are sometimes grooved and tongued down their edges so as to form a tight joint, and sharpened to an edge at the lower end which may be shod with iron.

In using sheet piling to enclose soft ground long "guide piles," about 6 to 10 feet apart, are first driven in the direction required.

On opposite sides of these are fixed beams ("string pieces" or "wales") at a horizontal distance apart just equal to the thickness of the sheet piles, which are driven down between them, commencing at the guide piles, and working inwards in each bay, so that the last sheet pile driven acts as a wedge and tightens up the whole.

PILE FOUNDATIONS.—*Platform on Piles.*—After the piles are driven, and their heads sawn off level, a timber platform is generally laid upon them.

This consists of heavy square balks, called string pieces and cross pieces, notched into one another so as to form a grating or "grillage." The string pieces are notched over the heads of the piles, and secured to them by trenails.

The ground between the piles is often taken out to a depth of 3 or 4 feet, and the space filled with concrete. The intervals between the timbers of the platform are sometimes similarly filled in, and in some cases a bed of concrete is substituted for the platform altogether.

Fig. 401 is an illustration of a portion of pile foundation for a thick wall. P P P are the piles (shod in different ways), S S the string pieces, and C C the cross pieces. The platform Y Y is composed of Yorkshire landings 6 inches thick.

A portion of the foundation is secured by sheet piling, S P, driven between the waling, W, and the outer cross piece of the grillage.

A disadvantage in the string pieces and cross pieces is that the heads of the piles, bearing upon their sides, bend and crush into the longitudinal fibres, indenting the timber, and causing it to sink down upon the pile heads. Where there is a really good strong bed of concrete the string and cross pieces can, with advantage, be omitted; in fact, in many cases a good broad and deep bed of solid concrete enables the use of the piles themselves to be dispensed with altogether.

CAUSES OF FAILURE OF PILE FOUNDATIONS.—Pile foundations are liable to fail, from the softness of the ground being such that it does not offer sufficient resistance to a lateral movement, in consequence of which the piles lose their original position, and the wall has a tendency to upset.

Wooden piles are sure to be destroyed by rot in any position where they are alternately wet and dry.

If used in sea water they are liable to attacks from worms, by

which they are soon destroyed. These attacks can best be delayed by completely charging the pores of the timber with creosote (see Part III.), or they may be prevented for a time by covering the surface of the timber with scupper nails driven close

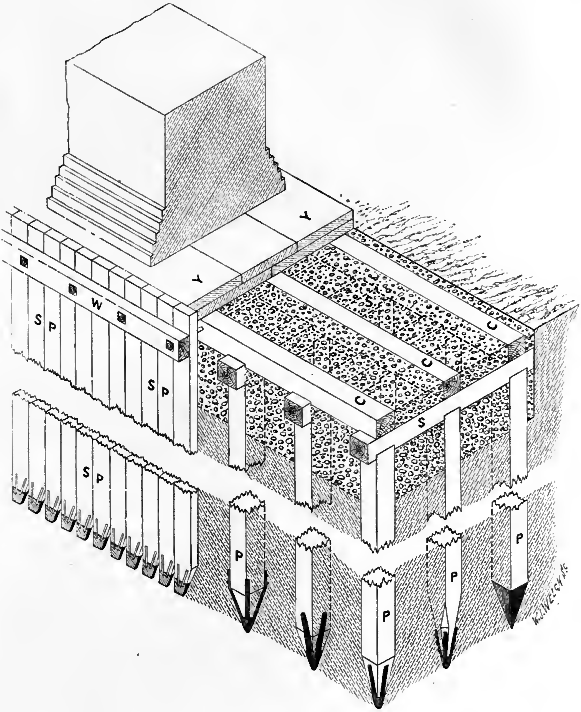


Fig. 401.

together, or, at a great cost, by sheathing the pile with copper. After a time, however, the worm manages to get under the nails or sheathing, and to eat the wood completely away, leaving an apparently sound but entirely hollowed pile. (For an account of the worms, etc., see Part III.)

Partial piling provided under a portion only of a wall is most

dangerous, as it leads to unequal settlement, by which the wall may be fractured.

In a wall with buttresses the unequal weight on the piles has led to failure.

Iron Piles have been introduced to avoid the natural defects of those made of timber.

Cast-iron Piles have been used of various cross sections, such as square, round, hollow, and cross shaped.

In driving them a block of wood or "dolly" must be interposed between them and the monkey, for fear of breaking the pile by the sudden shock.

They have a disadvantage for the foundations of buildings, inasmuch as they cannot be cut off to a level at the top.

Cast-iron sheet piling has been extensively used; it consists generally of flat plates, stiffened by vertical ribs, and furnished with overlapping edges. The guide piles may be of the same construction, square or semicircular in cross section.

Screw Piles.—In these the pile itself may be of timber, or a cylinder of cast or wrought iron.

It is furnished at the lower end with a short and broad cast-iron screw blade, which is twisted (Fig. 402) round under pressure so that it enters the ground, from which a great force would be required to withdraw it.

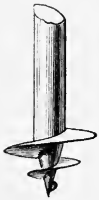


Fig. 402.

The best way of driving these piles is by attaching long radiating levers to the upper end, and turning them round by means of animals moving on a temporary platform.

Tubular Foundations.—These are generally composed of cast-iron tubes of large diameter united in lengths by internal flanges and bolts.

These cylinders are sunk by excavating the earth from within and under them in various ways. The water may be kept out of them by pumping in compressed air. The excavation can then be done by men working within the cylinder, or if the water is not forced out the excavation may be carried on by tools, or special excavating machines lowered from above. In cases where the soil is very soft, cylinders have been sunk by exhausting the air from within them, so that they are forced down by the atmospheric pressure acting upon their covers or upper surface.

Iron piles and tubes are more in use for the foundations of

engineering works than for ordinary buildings; they need not therefore be further noticed in this course.

Well Foundations.—With these the building rests upon a number of hollow cylinders, or wells, of brickwork or masonry, which form supports in the same way as hollow piles or tubular foundations.

The masonry is first built to a height of about 4 feet upon a wooden curb or frame of the size of the work; this is then undermined and allowed to sink its full depth into the ground; another 3 or 4 feet is then added, the structure is again undermined, and so on until the required depth has been attained.

The masonry must be of first-rate quality, and the undermining must be equal all round, or the work will be strained and crack.

Well foundations are extensively used for ordinary buildings in India; but in this country they have been restricted to cases in which a support is required for heavy wharf walls and other structures.

Pile Engines of various kinds are used for driving piles into the ground.

In all of them a heavy block of iron or wood called a "ram" or "monkey" is raised by a rope or chain over a pulley to the top of an upright frame and then allowed to fall suddenly upon the head of the pile, being guided in its descent by arrangements which vary considerably in different engines.

There is some difference of opinion as to whether piles are best driven by blows slowly delivered by a heavy monkey falling through a considerable height, or by a light monkey, with a short fall, delivering blows in quick succession. The latter plan is, however, in nearly every case by far the best, as the heavy blows crush the foot of the pile just above the shoe, convert it into a large mass or ball of fibres, which prevents it from penetrating further.

Ringing Engines.—In these the chain or rope attached to the monkey, after passing over the pulley at the head of the frame, is connected with several short ropes, each of which is hauled on by a man until the monkey has been raised 3 or 4 feet, when upon a given signal the whole are let go at the same moment so as suddenly to release the monkey, which falls upon the pile.

Immediately after the blow is delivered the men pull the rope so as to tighten it and take advantage of the rebound of the monkey from the head of the pile.

Fig. 403 shows a very simple form of ringing engine adapted for use by seven or eight men.

The frame consists merely of an upright pole or leader supported by two side braces, and steadied by guys secured to an iron strap at the head.

The monkey, M, here shown is of cast-iron, weighing from 250

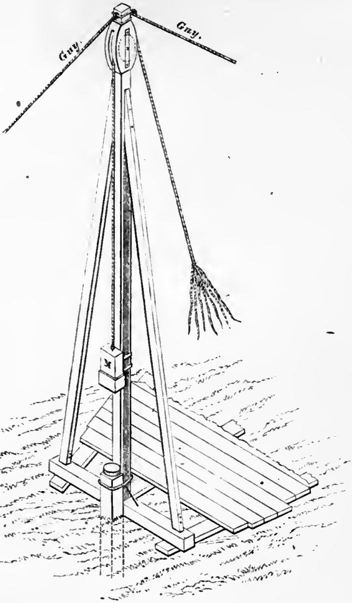


Fig. 403.

to 300 lb., and is guided in its descent by wrought-iron straps fixed to its sides, which embrace the "leader," and are secured at the back by a transverse bar passing through slits formed in the ends of the straps.

The rope shown round the head of the pile is intended to keep it close up to the engine so that it may not get out of place while it is being driven.

This engine is generally used for small piles; it delivers its

blows with great rapidity, the monkey being raised only as far as the men can reach, some 3 or 4 feet each time, and the rope never being detached from it.

In some forms of this engine a monkey weighing from 600 to 800 lb. is used.

In these a stronger and more elaborate framing is required. Two parallel leaders, L L, are generally made use of, connected by a cross head, and further supported by framing.

In such engines the monkey may be provided with ears and projections cast on its sides, which travel in grooves formed on the inner sides of the leaders and thus guide the monkey during its fall.

Professor Rankine recommends that the men to work such an engine should be in the proportion of 1 to every 40 lbs. weight in the monkey, and states that they work most effectively when after every three or four minutes of exertion they have an interval of rest, and that under these circumstances they can give about 4000 or 5000 blows per day.

Crab Engines are similar to the last described in their general arrangements, but the framing is much higher and the monkey is lifted to a height of 10 or 12 feet by means of a windlass or crab worked by men, horses, or steam-power.

In the commonest form the monkey is raised upon a hook, *h* (Fig. 404), attached to a counter-weighted lever, *l*, to the long arm of which is attached a rope, by pulling which the hook is pulled out and the monkey is permitted to fall.

The monkey can be released at any height by pulling the trigger rope C.

It is generally desirable that the height of fall should be the same for each stroke; this may be ensured by attaching the trigger-rope to the head of the pile.

Sometimes the rope is tied below, to the framing of the pile-driver, so as to cause the release of the monkey always at the same point, but in this case the height through which the monkey falls of course increases as the pile is driven further down.

The monkey should always descend in a line parallel to the direction of the pile. When that is vertical the guides are in the uprights of the framing, but if the pile is to be driven in an inclined position the guides must be similarly inclined, or if the framing will not permit this, temporary guiding pieces must be fixed at the required inclination.

Steam Pile-Drivers are those in which a small steam engine takes the place of the manual power applied to the crab. There

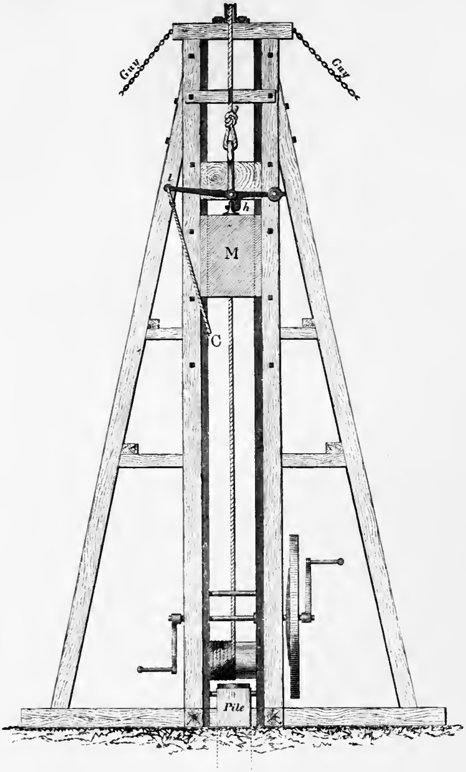


Fig. 404.

are several forms of steam pile-drivers, but it is unnecessary to describe them in these Notes.

A "*Punch*," or "*Dolly*," is a short post or block interposed between the head of the pile and the monkey, either when the former would otherwise be out of reach, or when it is advisable, as in the case of cast-iron piles, to deaden the blow.

"According to some of the best authorities the test of a pile's having been sufficiently driven is that it shall not be driven more than $\frac{1}{5}$ inch by 30 blows of a ram weighing 800 lb. and falling 5 feet at each blow.

"It appears from practical examples that the limits of the safe load on piles are as follows:—

"In piles driven till they reach the firm ground, 1000 lb. per square inch of area of head.

"In piles standing in soft ground by friction, 200 lb. per square inch of area of head."—RANKINE.

DRAWING PILES.—This may be necessary when a pile breaks, or for other reasons.

It is generally effected by fastening the head of the pile to a long beam and using the latter as a lever, or it may be done by means of the hydraulic press.

A pile may also be drawn by means of a large screw, one end of which is fastened to the head of the pile while the other passes through a cross head temporarily but firmly supported above it.

INVERTED ARCHES are used for distributing uniformly over a foundation the pressure of a building, which in some cases would otherwise come only upon a few points.

For instance it is evident that in the building shown in Fig. 405 there would, in the absence of the inverted arches, be a great pressure upon the foundation immediately under the abut-

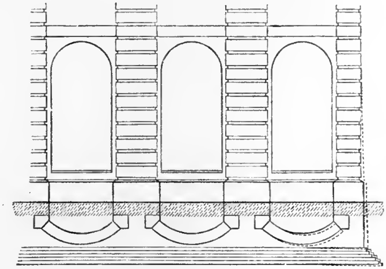


Fig. 405.

ments and piers, but none at all on the portions under the voids; the arches, however, cause the weight to be uniformly distributed over the whole.

Such arches are of course only necessary when the foundation is of a compressible nature.

Arches of 9 inches in thickness are sufficient for ordinary pur-

poses, but for large and heavy buildings they may be increased in thickness; the angle subtended by the arch should not be less than 45°.

It is most important that inverted arches should have an efficient abutment on both sides; if not, they may do more harm than good by thrusting out the corner of the wall as shown in dotted lines in Fig. 405.

When a chasm or bad soft place occurs in a foundation immediately under a pier and cannot be filled up, it may be bridged over by an ordinary arch whose extremities spring from or rest upon those of the inverted arches which lie under the openings on either side; or, where there are no inverted arches, the ordinary arch may spring from the sides of the chasm.

CHAPTER XII.

MATERIALS.

FULL information with regard to the materials used in the construction of buildings is given in Part III. of this work. This chapter will contain only so much as is necessary to meet the requirements of the Second Stage or Advanced Course.

BRICKS.

Manufacture.—Ordinary building bricks are made of clay or other earths subjected to various processes, such as clearing from stones, grinding if necessary, and mixing in some cases with chalk. These vary somewhat according to local practice, influenced by the nature of the material. The clay is formed, after mixing with water to a plastic condition, to the required shape by hand in moulds, or by machines, dried, and then burnt either in *kilns* (large ovens) or *clamps* (piles of the dried bricks themselves).

HAND-MADE BRICKS have a *frog*, or indentation, on one side, which lightens the brick and forms a key for the mortar.

MACHINE-MADE BRICKS are generally denser and heavier than those made by hand. In some machines the bricks are cut off by a wire: they then have no frog; in others the clay is pressed when nearly dry in a mould, and these generally have a frog, and are often pierced through with holes to make them lighter.

Classification of Bricks.—This differs in various localities, but in some brickfields near London there are three general classes:—

Malms, in which the clay is mixed with about $\frac{1}{16}$ chalk, and cinders.

Washed, in which less chalk is added to the clay.

Common, in which no chalk is added.

These classes are divided into several varieties, the principal of which are—

Cutters or *Rubbers* of even texture and very soft, so that they can be cut and rubbed to accurate shapes and to a smooth face.

Facing Paviors, hard-burnt malm bricks of good shape and colour, used for facing superior work.

Hard Paviors are more burnt, slightly blemished, and used for copings, superior facing, etc.

Stocks, good hard bricks, used generally for ordinary good work.

Grizzles and *Place Bricks*, which are weak, under-burnt, inferior bricks.

Chuffs are bricks on which the rain has fallen when they were hot, making them full of cracks and useless.

Burrs are lumps of over-burnt bricks vitrified and run together.

MACHINE-MADE BRICKS may be classed as *Pressed* or *Wire-cut*, of each of which there are several varieties.

Characteristics of good ordinary Bricks.—They should be well burnt, hard, ringing well when struck together, free from cracks and lumps, especially lumps of lime, regular in shape and uniform in size, not absorbing more than $\frac{1}{6}$ of their weight of water.

Size and Weight.—This varies; but near London ordinary bricks are about $8\frac{3}{4}$ inches long, $4\frac{1}{4}$ inches broad, and $2\frac{1}{2}$ inches thick, and weigh about 7 lbs each.

In order to obtain good brick-work, the length of each brick should just exceed twice its breadth by the thickness of a mortar joint.

Varieties of Bricks.

Besides the ordinary bricks above described there are innumerable varieties in the market, the most important of which are:—

WHITE BRICKS, made from peculiar clays, sometimes with the addition of a large proportion of chalk. The best known are the *Suffolk* and *Beaulieu* bricks.

Gault Bricks are from the clay between the upper and lower greensand. They are white, and generally very dense and heavy, being to some extent lightened by a large frog, or by holes through their thickness.

STAFFORDSHIRE BLUE BRICKS are made from the local clays, which contain some 10 per cent of oxide of iron, converted under great heat into the black oxide. They are of a dark blue colour or nearly black. They have an enormous resistance and compression, are very hard, non-porous, very durable, and much used for paving, copings, etc.

FAREHAM RED BRICKS are made near Portsmouth, and are much used for superior face-work.

ENAMELLED BRICKS have a white china-like surface, and are used for lavatories, dairies, etc.

DUTCH CLINKERS are very small, well-burnt hard bricks, used for facing.

MOULDED and PURPOSE-MADE BRICKS may be obtained of every possible form, and not only save much labour in cutting ordinary bricks, but weather much better, being as a rule of better material.

Fire Bricks are made from "fire clays," found generally in the coal-measures. They are capable of withstanding very high temperatures, and are much used for lining furnaces, etc.

Terra Cotta is made from mixtures of peculiar clays with ground glass,

pottery, and sometimes sand. It is apt to warp in manufacture, but is much used for building, is very hard, strong, and durable in any atmosphere.

Pipes and Clay Goods.—These are innumerable in form, but it is important to distinguish between the material of which they are made.

Unglazed ware is made from ordinary clays, weak, and unable to resist frost.

Fire-clay Ware, made from fire clays and glazed, used for common work.

Stoneware, made from Lias clays, glazed, is very strong, durable, and used for the best work.

Terra Cotta, made from the material above described. It is inferior to stoneware, being more absorbent, but better than fire-clay goods.

STONE.

Characteristics of good Building Stone.—Stone is found of many different descriptions and qualities, but the chief characteristics required in a good stone for building are as follows :—

DURABILITY, which depends chiefly upon chemical composition ; for a large proportion of lime will render the stone unfit to resist the acid atmosphere of towns—a stone that is not durable out of doors is said to "weather" badly. The durability is, however, to some extent influenced by its PHYSICAL STRUCTURE, thus marble is more durable than chalk, though chemically the same. HARDNESS (for quoins, etc.), FACILITY FOR WORKING (for carvings, etc.), and APPEARANCE, have sometimes to be considered.

Classification of Building Stones may be taken as follows :—

Granites and other igneous rocks.	Sandstones.
Slates.	Limestones.

Granite is composed of quartz, felspar, and mica. It is, as a rule, very durable and hard to work, and is used for heavy engineering structures and for massive buildings, also in the parts of ordinary buildings, such as steps, that undergo most wear.

Mica and some kinds of felspar are liable to decay, but quartz is always hard and durable ; therefore the more quartz a granite contains the better.

The best-known granites are found in Scotland and Cornwall.

Slates for Roofing.—They should be fine grained, hard, with a metallic ring, not friable at the edges ; tough, so as not to splinter when cut or holed ; and non-absorptive. The best varieties come from Wales.

Slate is also used in slabs of from 1 to 3 inches thick for cisterns, sills, skirtings, landings, etc.

Sandstones are found in great variety. They consist of grains of sand held together by cementing material, upon the nature of which latter depends their durability.

The best-known sandstones are as follows :—

YORKSHIRE SANDSTONES.—These have a coarse grit, are very strong, can be obtained in large blocks of a light brownish-white colour, and are much used for heavy engineering work. The best-known quarries are *Bramley Fall*, *Bradford*, *Scotgate Ash*, etc. etc.

MANSFIELD STONE is found in Nottinghamshire in two colours, red and white, and is well adapted for ashlar work, columns, etc.

CRAIGLEITH STONE, found near Edinburgh, is the most durable sandstone in the country, and useful for any good masonry.

Limestones consist of grains of carbonate of lime cemented together by the same substance, or by the same mixed with silica.

They vary greatly in texture, being either *granular*, with grains varying much in size, or *compact*, not showing grains.

The principal varieties are :—

BATH STONE.—An even-grained, comparatively soft white stone ; some of it weathers badly. It is obtainable in large blocks, and much used for mouldings and carved work. There are several quarries, such as Box, Combe, Corsham, etc.

PORTLAND STONE.—Several distinct kinds are found in the quarries. *Roach and Whitbed Roach* are full of shell casts, and not much used in ordinary buildings. *Whitbed* and *Basebed*, known also as "*Bestbed*," are most valuable white building stones, of even texture, and durable in most positions. Both descriptions present the same appearance, but Whitbed is harder to work and more durable than the other.

KENTISH RAG is a hard, compact, non-absorbent gray stone, very difficult to work, and used chiefly for rubble. (See Part I.)

YELLOW MANSFIELD STONE is a magnesian limestone, composed almost entirely of carbonate of magnesia and lime, and is an even-grained stone fit for ashlar and carving.

CAEN STONE is found in Normandy, but much used in this country. It is of a cream colour, very soft when just quarried, easily worked and carved, but weathers badly.

Marble is a very dense, compact form of limestone that will take a polish ; some varieties are beautifully marked, and are used chiefly for decorative purposes.

Natural Bed.—The importance of placing stones in walls with their natural beds—in the layers in which they were geologically deposited horizontal—has been mentioned in Part I. ; also that in cornices or over hanging work the natural bed should be vertical.

LIMES AND CEMENTS, MORTAR, GROUT, CONCRETE, ETC.

LIME.

Quicklime is produced by burning limestone in a kiln, the carbonic acid is driven off, and the result is quicklime.

Slaking is effected by thoroughly wetting a quicklime and covering it up. It then swells, becomes hot, gives out puffs of steam and falls to powder, which is called *slaked lime.*

The slaking process is very violent with rich limes, less so with poor limes, and very slight in the case of hydraulic limes.

Setting.—When a lime or cement is made with water into a pat, and exposed to the air, it will harden less or more according to its quality, until in most cases it becomes quite hard throughout its bulk. With hydraulic limes and cements the hardening will take place even better if the pat is placed under water.

Pure, Rich, or Fat Lime is that produced from pure limestones, such as marble or chalk, containing nothing but carbonate of lime. Such a lime slakes furiously, but a pat made from it will never thoroughly set or harden, even in the air, and if placed under water it will simply dissolve away. Rich limes cannot, therefore, make good mortar or concrete, but are the best for whitewashing and sanitary purposes.

Poor Lime is from limestone containing useless impurities, and it shares all the defects of rich limes.

Hydraulic Limes are produced from limestones which contain from 5 to 30 per cent of clay in a peculiar form. They slake with more or less difficulty, but will set, becoming quite hard in air or under water, and are therefore adapted for making good mortar and concrete.

TEST.—To ascertain whether a limestone is hydraulic, it should be made red hot, to drive off the carbonic acid. The resulting quicklime should be slaked, made up with water into a pat, and then placed under still-water, to see if it will set there. If it does not set, but dissolves or becomes disintegrated, it will show that the lime is not hydraulic.

CEMENTS.

Cements are either natural or artificial.

Roman Cement is the best-known natural cement in this country. It is made by burning nodules containing some 30 to 45 per cent of clay, found in the London clay. This cement is of a rich brown colour, and weighs about 75 lbs. a bushel. It sets in about 15 minutes, and is valuable for tide-work, or stucco, but its ultimate strength is very small.

Other quick-setting Cements.—For the names and uses of other somewhat similar cements, see p. 178. They are not used for mortar or concrete, but chiefly for plasterers' work.

Portland Cement is an artificial compound made by mixing chalk and clay in water in the proportion of about 75 per cent chalk to 25 per cent clay, drying and burning the mixture in kilns, and grinding the resulting "clinker" to such a fineness that 90 per cent of it will generally pass a sieve of 2500 meshes to the square inch, and it will weigh about 115 lbs. per bushel.

The result is a fine powder of greenish gray colour, which when mixed into a pat will set either in the air or under water, becoming hard in twenty-four hours, attaining considerable tensile strength in seven days, and in course of time a strength far greater than that of any other cement.

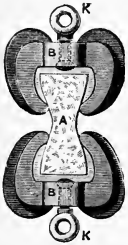


Fig. 406.

Testing.—The tensile strength of samples of Portland cement is ascertained by forming the cement into *briquettes* or blocks, of the form shown in Fig. 406, the section at A being generally $1\frac{1}{2}$ inch square. These are broken in a machine which applies slow tension upwards and downwards at K and K.

A good cement after setting seven days under water is expected not to break under a less weight than of about 800 lbs. on the area A ($2\frac{1}{4}$ square inches), *i.e.* 355 lbs. per square inch.

Cooling.—It is of the utmost importance that Portland cement should be thoroughly *cool* when used—all the lime in it thoroughly air-slaked—otherwise it may swell in the work when used, and cause much damage. In order to cool it, it should be spread out on a floor protected from the weather, and turned over daily for some weeks, so that every part of it may become thoroughly air-slaked.

MORTAR—CONCRETE.

Mortar is made by mixing to the consistency of soft porridge limes or cements with clean sands, the proportion of which depends upon the description of the lime or cement.

Proportion of Sand.—*Rich and Poor Limes* may be mixed with a large proportion of sand (3 or 4 measures of sand to 1 of lime), for in any case they make mortars with very little strength. *Hydraulic Limes* make a good mortar with 2 of sand to 1 of lime. *Roman Cement Mortar* should not have more than 1 or $1\frac{1}{2}$ sand to 1 cement, and is then a very weak mortar. *Portland Cement* will make a very strong mortar when mixed with 2 or 3 of sand, and even with 5 of sand—a mortar better than any of those made from lime.

Grout is a weak mortar made liquid by the addition of water, and used to pour into joints and interstices which cannot be got at with the stiffer material.

Concrete is a conglomerate or thorough mixture of shingle, broken stones, or similar material, with lime or cement, sand and water, which form a mortar filling the interstices between the pieces of stone. The proportions of ingredients mixed determine the quality of this mortar, which in its turn governs the strength of the concrete.

PROPORTIONS OF INGREDIENTS.—Concrete is generally described with reference to the bulk (when dry) of the materials comprising it. Thus for an important work the concrete might be 1 Portland cement, 2 sand, and 5 of shingle or broken stone; for less important work 1 Portland cement, 3 sand, and 8 shingle.

LAYING CONCRETE.—This should be carefully done in horizontal layers, about 12 inches thick, well rammed, the surfaces being kept clean, and the material not disturbed when setting.

PLASTER AND ASPHALTE.

Plaster for common work is a sort of mortar spread over surfaces to make them smooth. It is laid on in successive coats, the composition of which varies, and is given at pp. 178-179.

PLASTER OF PARIS, or calcined gypsum, is a very quick-setting material, the basis of several cements, for which see p. 178.

Asphaltes are combinations of bituminous and calcareous matter. The best are natural—found chiefly in Switzerland—but there are many artificial imitations made with pitch and chalk.

The material is generally heated, and poured in a molten state over the surface to be covered. Some kinds are laid as powder and compressed by ramming.

The best varieties of asphalte are from Seyssel, and Val de Travers in Switzerland.

TIMBER.

Appearance of Cross Section.—The timber used in engineering and building works is obtained from a class of trees which grows by the deposit of successive layers of wood outside under

the bark, while at the same time the bark becomes thicker by the deposit of layers on its under side.

ANNUAL RINGS.—The cross section of such trees (see Fig. 407) consists of several concentric rings or layers, each ring consisting in general of two parts—the outer part being usually darker in colour, denser and more solid than the inner part. The difference between the parts varies in different kinds of trees.

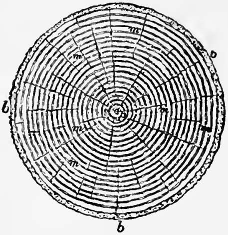


Fig. 407.

These layers are called *annual rings*, because one of them is, as a rule, deposited ever year. Sometimes, however, a recurrence of exceptionally warm or moist weather will produce a second ring in the same year.

MEDULLARY RAYS AND SILVER GRAIN.—In the centre of the tree is a column of pith *p* from which planes, seen in section as thin lines *m m*, radiate toward the bark *b*, and in some cases similar lines *m m* converge from the bark toward the centre but do not reach the pith.

These radiating lines are known as "medullary rays" or "transverse septa." In many woods they are not discernible by the eye, but when they are of large size and strongly marked, as they are in some kinds of oak, they present, if cut obliquely, a beautiful figured appearance, known as "silver grain" or "felt."

HEARTWOOD AND SAPWOOD.—As the tree increases in age the inner layers are filled up and hardened, becoming what is called "heartwood," the remainder being called "sapwood." The latter is softer and lighter than heartwood and can generally be easily distinguished from it.

This is important, as the heartwood is in most trees far superior to the sapwood in strength and durability, and should alone be used in good work.

Characteristics of good Timber.—Good timber should be from the heart of a sound tree—the sap entirely removed. The wood, uniform in colour and substance, straight in fibre, free from large or dead knots, flaws, shakes, or blemishes of any kind.

The annual rings should be regular in form; close and narrow rings indicate strength, porous and open rings are signs of weakness. Good timber is sonorous when struck. A dull heavy sound betokens decay.

Classification of Timber.—For practical purposes timber may be classed as :—

SOFT WOOD, including fir, pine, spruce, larch, and all cone-bearing trees.

HARD WOOD, including oak, beech, ash, elm, mahogany, teak, etc.

Market Forms of Timber.—The following are the most common forms in which timber is sold :—

Logs, being trunks of trees with the branches lopped off.

Balks or *square timber*, being the trunks roughly squared, generally by the axe, sometimes by the saw.

Planks, being parallel-sided pieces 2 to 6 inches thick, 11 inches wide, and from 8 to 21 feet long.

Deals. Similar pieces 9 inches wide, and not more than 4 inches thick.

Battens, being like deals, but only 7 inches wide.

DESCRIPTIONS OF DIFFERENT KINDS OF TIMBER.

SOFT WOODS.

Red or Yellow Fir, or *Northern Pine*,[1] is obtained chiefly from the Baltic or Russia.

Its cross section shows distinct annual rings, the hard portions of which are much darker than the others ; the wood is resinous, and there are no medullary rays visible.

The best timber of this description comes from *Memel, Dantzic*, and *Riga*, the balks being from 18 to 45 feet long and 12 to 16 inches square.

Yellow Deals come from the same ports, the best from *St. Petersburg, Archangel* ; and others from *Christiania*, and from *Gefle* and other Swedish ports.

All these are used for carpenters' work, and the best of the deals for joinery.

American Pine.—*Red Pine*,[2] so called from the colour of its bark, very like Memel tibmer, and *Yellow Pine*,[3] of a brownish-yellow colour when seasoned, are imported from Canada.

AMERICAN YELLOW PINE is of a very soft and even grain, and can be easily recognised by short, detached, dark, thin hair-streaks running in the direction of the grain, which show upon a planed surface.

It is invaluable for joinery, but is not so strong or durable for carpenters' work as Baltic timber.

Pitch Pine[4] also comes from North America. It has very strongly-marked annual rings, is full of resin when it has not been "bled," hard to work and to wear, very durable except in a moist atmosphere.

It is much used for heavy engineering structures, also for ornamental joinery and for parts, such as heads of steps, sills, etc., subjected to much wear.

Spruce,[5] or *White Fir*, comes both from the north of Europe and from North America.

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[1] Obtained from the *Pinus sylvestris* or *Scotch Fir*.

[2] Known also as *Canada Red Pine, Pinus rubra*, or *Pinus resinosa*.

[3] *Pinus strobus.* [4] *Pinus rigida.* [5] *Abies excelsa.*

The wood is of a yellowish white, with clear annual rings and hard glossy knots, by which it is easily recognised.

It shrinks and warps very much, and is fit only for common joinery and floors, packing-cases, and other common work.

Larch is found in various parts of Europe, the best being in Russia.

It is of a brownish-yellow colour, the hard parts of the rings being reddish. The wood is tough and durable, but shrinks and warps, and is used chiefly for posts and palings.

HARD WOODS.

Oak is found both in this country and also in America, Holland, and the Baltic.

BRITISH OAK is found in three principal varieties[1] which need not be described in detail.

It is in section of a light brown colour, with a hard surface, narrow and regular annual rings, and clearly-marked medullary rays.

The timber is very strong, hard, tough, and durable; is used for all purposes where strength and durability are required in engineering structures, and in buildings for sills, treads, superior joinery, keys, wedges, etc.

AMERICAN OAK[2] has a straighter and coarser grain than English oak, but is not so strong or durable.

DANTZIC, RIGA, and ITALIAN OAKS are chiefly used for ship-building.

FRENCH OAK is very like British oak.

WAINSCOT is a form of oak that comes chiefly from Holland and Riga, is easily worked, and is so converted as to show the *silver grain*.

Beech is of a whitish-brown colour, with very distinct medullary rays and perceptible annual rings. The wood is hard, compact, and smooth, not difficult to work, very durable if always dry or always submerged, but decays quickly under alternate wet and dry or in damp places. It is used chiefly for piles, wedges, and carpenters' tools.

Ash is of a brownish-white, with yellow streaks, each annual layer separated from the next by a ring of pores. The sapwood is not generally distinguishable. The timber is tough, flexible, and durable when dry. It is too flexible for building purposes, and is used chiefly for tool handles and felloes and spokes of wheels.

Elm is found in several varieties. The heartwood is reddish-brown and the sapwood yellowish. No medullary rays visible. The wood is very fibrous, dense and tough, durable—the sapwood as well as the heartwood, except when alternately wet and dry. It is very useful for work under water, such as piles, and for various carpenters' purposes.

Mahogany is imported chiefly of two descriptions, *Honduras* or *Bay Mahogany* and *Spanish Mahogany*, the latter from Cuba.

The wood is of a golden-brown colour, often very veined and mottled, capable of receiving a good polish, and durable when dry and not exposed to weather. The *Spanish* is distinguished from the *Honduras* by a chalk-like substance in its pores. Both descriptions are used for handrails and furniture.

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[1] Stalk-fruited or Old English Oak, *Quercus robur* or *Quercus pedunculata.* Cluster-fruited or Bay oak, *Quercus sessiliflora.* Durmast oak, *Quercus pubescens.*

[2] White oak (*Quercus alba*) or *pasture oak.* Other kinds are also imported.

Teak or *Indian Oak* comes chiefly from Burmah. It somewhat resembles English oak, but has no visible medullary rays. It is stronger and stiffer, but splinters easily. It contains an aromatic resinous oil, which makes it very durable.

This timber is too expensive for general use in buildings, but is sometimes employed for treads of steps, floors, etc.

Greenheart comes from South America. Its section is full of pores like that of a cane, of a dark green colour, the sapwood not distinguishable from the heart, and the annual rings not perceptible.

It is the strongest timber in use, and contains an essential oil which preserves it for a time from the attacks of worms. These qualities make it very valuable for marine work, in which it is much used.

Seasoning.—Timber is best seasoned, and the sap dried up, by being stacked under cover with the air circulating freely round it. There are methods of seasoning by hot air, also by boiling and steaming, and other special processes, which cannot here be described.

Decay.—When timber is in positions where it is alternately wet and dry, or not well ventilated, it soon decays, the sapwood being generally the first affected.

Dry Rot takes place in confined positions. A fungus eats into the timber, makes it change colour, smell disagreeably, become brittle, and eventually reduces the fibres to powder.

Wet Rot occurs in the growing tree, and in positions where the gases generated can escape.

Preservation.—The best method of preserving timber from decay is to have it thoroughly seasoned and placed in well-ventilated positions.

Painting or *Charring* preserve timber if it is thoroughly seasoned; if not, they do harm by confining the moisture and causing rot.

Creosoting consists in forcing creosote (oil of tar)[1] into the pores of the timber, by which the albumen of the wood is coagulated, worms repelled, and rot prevented.

There are many other methods of preserving timber, which are described in Part III.

Felling Timber.—The best season for felling timber is at midsummer or midwinter in temperate, or during the dry season in tropical climates, when the sap is at rest.

The age at which a tree should be felled varies with circumstances. The heartwood must be fully formed, but the tree must not have passed its maturity, which will be shown by the presence of young shoots and vigorous top-branches.

IRON AND STEEL.

Iron is produced by smelting different ores with a flux, which

[1] See Part III. p. 395.

extracts from them most of their impurities. The liquid iron runs out of the blast furnace into rough bars called "*pigs.*"

Hot Blast Iron is that produced by furnaces into which the air is admitted at a high temperature. When the air is not thus heated the resulting metal is known as *Cold Blast Iron*. There are but few cold blast furnaces now in the country.

PIG IRON.

Carbon in Pig Iron.—The bars or pigs run from the blast furnace are not pure iron, but contain several impurities, such as carbon, silicon, sulphur, phosphorus, and manganese.

Of these carbon is the most important. It is sometimes free, being visible as black specks, sometimes chemically combined when it is not visible.

EFFECT OF CARBON.—The effect of the *uncombined or free carbon* is to give a fractured surface of the iron gray colour, and to render it easily fusible.

The *combined carbon* does not show in the fractured surface, which is white and bright, the iron being very hard, brittle, and forms when fused a pasty mass, which will not freely fill a mould.

DIFFERENCE OF CARBON IN IRON AND STEEL.—It is important to remember that the materials produced from pig iron differ considerably as to the amount of carbon they contain, upon which depend many of their characteristics.

These materials are :—

Cast iron, containing from 2·0 to 6·0 per cent of carbon—a comparatively large percentage.

Steel, containing about ·15 to 1·8 per cent—a small percentage.

Wrought iron, containing, if perfectly pure, no carbon, but practically containing a trace.

Classification of Pig Iron.

Bessemer Pig, a distinct variety, free from impurities, but containing a little manganese and silicon ; made for the Bessemer process (see p. 251).

Foundry Pig, having a fracture of a gray colour, and useful to the iron founder.

Forge Pig, being almost devoid of free carbon, not fit for superior castings, but only for conversion into wrought iron.

Besides the above varieties, the pig iron of commerce is divided into six or eight classes.

CAST IRON.

Cast iron is obtained by remelting pig iron with a little limestone flux to get rid of its impurities, and running it into moulds.

Classification.—Gray Cast Iron is made from foundry pigs. No. 1, the darkest in colour, contains a large proportion of free carbon; is soft, very fluid when melted, and useful for very delicate castings. No. 2 is lighter in colour, less fluid, but is harder than No. 1 when cold, and good for casting girders, etc. No. 3 is of a still lighter colour, harder, more brittle, and adapted for heavy castings.

White Cast Iron is made from forge pigs; is very bright, hard, and unfit for castings, except the commonest, such as sash weights.

Mottled Cast Iron contains both gray and white, which can easily be distinguished on a fresh fractured surface.

The Structure of Cast Iron is highly crystalline; a bar broken across shows no sign of fibre—nothing but crystals close together.

Castings are made by running molten cast iron into sand, in which an impression of the article to be cast has been formed by means of a wooden pattern.

The shape given to castings is important. There should be no sudden changes of thickness, or sharp angles as in Fig. 408, but the thickness should change gradually and the angles be rounded off as in Fig. 409.

If these precautions are not attended to the casting will crack at the angles, or at any rate have a tendency to do so.

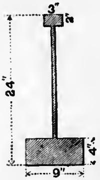


Fig. 408.

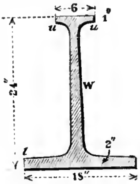


Fig. 409.

All castings should be smooth in surface, free from air bubbles or flaws, with perfect edges.

Chilled Iron is a very hard substance like white cast iron; it is produced on parts of castings which are required to be especially hard by placing pieces of cold iron against those parts when the metal is being run in.

Thus the running surface of a cast iron wheel may be chilled and made hard, the rest of the wheel being of a tough gray cast iron.

Malleable Cast Iron is made by extracting some of the carbon from cast iron, thus making it more like wrought iron in composition, which produces its toughness.

This is done for small castings by imbedding them in oxide of iron and raising to a red heat.

Iron so heated is softened to a certain depth all over the surface, and can be hammered or bent to a certain extent.

WROUGHT IRON.

Manufacture of Wrought Iron.—Wrought iron is manufactured from forge pig by the following processes.

Refining, or exposure when fused to a strong current of air which removes part of the carbon.

Puddling, by which the molten metal is still further exposed to a blast of air and oxidising substances in a reverberatory furnace. The remainder of the carbon is thus removed, and clotty lumps or "*puddle balls*" of pure iron appear.

Shingling, or hammering of these puddle balls so as to squeeze out the cinder and form them into "*blooms.*"

Rolling, or passing the blooms while red hot between grooved rollers which convert them into *puddled bars.*

The effect of rolling is to elongate the crystals of the pig iron into *fibres,* giving the iron great strength and toughness.

Bar Iron is classified as follows:—

Puddled Bars, as obtained by the processes just mentioned, have but little tensile strength, and are used only for manufacture into better descriptions.

Merchant Bar or *Common Iron* is made by piling up short lengths of puddle bars, raising them to welding heat, and re-rolling. This improves the fibre of the iron, which is, however, still very hard, brittle, and useful only for the commonest purposes.

Best Bar is produced by cutting up merchant bars, piling, reheating, and rolling. It is tougher and more easily worked than merchant bar, and is generally used for ordinary good work.

Best Best and *Best Best Best* iron bars are those that have been submitted to three and four repetitions of the processes of piling, welding, and rolling.

The Market Forms of Wrought Iron are very various. Besides square, round, half-round, flat, and other sections of bars, the sections shown below are the most common, and Figs. 410 to 414 are useful in building up iron structures of all kinds. The name of each is given below it.

Angle Irons. Figs. 410, 411. — T Irons. Figs. 412, 413. — Channel Iron. Fig. 414.

I Beam or Joist.

Fig. 415.

Double-headed Rail.

Fig. 416.

Flat-bottomed Rail.

Fig. 417.

Tram Rail.

Fig. 418.

Sash Bar.

Fig 419.

Corrugated Sheet Iron is made by passing sheets through grooved rollers which force them into waves or corrugations that immensely increase their stiffness and make them useful for roofing and other purposes.

Galvanised Iron is iron covered with a coating of zinc which protects it from oxidation.

Tests for Wrought Iron.—For all structures of any degree of importance the tensile strength of the wrought iron used should be tested.

A good iron should not only be strong but ductile, in order that it may not snap suddenly but stretch slightly under the shocks to which it may be subjected.

Such iron when torn asunder by slow tension in a testing machine should not break off short as in Fig. 420,[1] but draw out

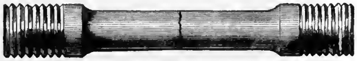


Fig. 420.

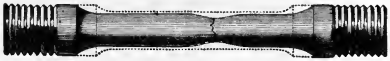


Fig. 421.

as in Fig. 421,[1] not only becoming longer, but also being reduced in sectional area at and near the point of rupture.

Tensile Strength and Elongation.—In order that both strength and ductility may be secured, engineers generally specify that iron bars for important work should bear a tensile stress of 23 or 24 tons per square inch, with an elongation of 30 to 40 per cent. Angle irons, T irons, and Plates have lower, and rivet iron higher tests.

Rough and Forge Tests.—Iron may be further tested by being bent hot or cold to different angles, the limbs of T and angle irons being flattened down and rivets doubled cold without showing any signs of fracture. If they can stand such tests without cracking they are of good quality.

Fractured Surface.—"Whenever wrought iron breaks *suddenly* a crystalline appearance is the invariable result; when *gradually*, invariably a *fibrous* appearance."[1]

Small uniform crystals or fine, close, silky fibres indicate a good iron. Coarse crystals, flaws, blotches of colour, loose and open fibres, are signs of bad iron.

[1] From Kirkaldy's *Experiments on Iron and Steel.*

STEEL.

Steel varies very much in its characteristics according to the amount of carbon it contains.

Thus *Mild or Soft Steel* contains from ·2 to ·5 per cent of carbon. When more carbon is present it becomes *Hard Steel.*

CHARACTERISTICS.—Speaking generally, the following are the characteristics of steel.

Hardening.—When raised to a red heat and suddenly cooled it becomes hard and brittle, thus differing from wrought iron, upon which this treatment has no effect.

Tempering.—After hardening as above, the steel may be softened again to any degree by reheating and again cooling; in this it differs from cast iron.

Other characteristics of steel are its sharp *metallic ring* when struck, its great *elasticity,* and its *retention of magnetism.*

Methods of making Steel.—Steel is generally made by adding carbon to pure wrought iron (see p. 247).

Blister Steel is produced by heating bars of the purest wrought iron with charcoal (carbon).

It has a crystalline structure, is covered with blisters and full of cavities, which render it unfit for edge tools, and it is used chiefly for conversion into better descriptions of steel.

Shear Steel is made by piling short lengths of blister steel and welding them together under the hammer, which closes the cavities, removes the blisters, and produces a more uniform material known as *Single Shear Steel.* A repetition of the piling and welding produces *Double Shear Steel.* Shear steel is used for large knives, plane irons, shears, etc.

Crucible Cast Steel is made by melting blister steel in crucibles, or by melting wrought iron with the addition of the necessary carbon in the form of charcoal. It is used for the best tools and cutlery.

Bessemer Steel is produced direct from pig iron which, when melted in a "converter," is deprived by a blast of air through it of all its carbon, the amount necessary to convert it into steel of the softness required is then added in the form of *spiegeleisen,* a variety of cast iron rich in carbon. The resulting metal is run out into ingots, which are hammered, rolled, and worked to the forms required.

Bessemer steel is much used for rails and for the tyres of wheels, also for large roofs and bridges, boiler-plates, etc.

The Basic Process is somewhat similar to Bessemer's, but that the converters are lined with material which deprives the pig iron of some of its impurities, thus enabling iron from the less pure ores to be converted.

The Siemens-Martin Process consists in melting pig iron in a regenerative furnace and then adding various substances, so that the molten metal may contain the exact amount of carbon necessary to produce the description

of steel required. Steel made by this process is much used for rails, tyres, bridges, roofs, boiler-plates, etc.

Puddled Steel is made by stopping the puddling process before all the carbon has been removed. It is a poor material, used chiefly for making inferior plates.

Case-hardening is a process by which the surface of wrought iron is turned into steel. This is effected by red-heating the article to be case-hardened when immersed in bone dust, which adds carbon to the surface and turns it into steel to the depth of from $\frac{1}{16}$ to $\frac{3}{8}$ inch. The parts required to be hardened are then quenched. The process is useful for keys, and other articles where a hard surface is required to be combined with toughness.

Tests for Steel.—The remarks made at p. 250 with regard to the tests for wrought iron, and the fractured surface, apply also to steel, except that in the case of steel the forge tests are much more important than for iron.

A recent specification for a large steel bridge requires that the bars and plates must have a tensile strength of not less than 28 tons or more than 31 tons per square inch, an elongation of not less than 20 per cent and a limit of elasticity of 15 tons. Besides this there are tests as to welding and tempering, too elaborate to be described here.

Working Stresses for Iron and Steel.—The ultimate tensile stresses to which iron and steel are subjected when tested are the *breaking stresses*. When, however, they are used in structures it is so arranged that the members of iron and steel should be subjected only to safe *working stresses* such as certainly will not cause fracture.

Table of Breaking and Working Stresses for Materials for a Dead Load.

Material.	Breaking Stress in Tons per square inch.		Working Stress in Tons per square inch.	
	Tension.	Compression.	Tension.	Compression.
Cast Iron	9	48	$1\frac{1}{2}$	8
Wrought Iron	23	18	5	4
Steel	32	32	$6\frac{1}{2}$	$6\frac{1}{2}$
Timber, Fir	$4\frac{1}{2}$	3	$\frac{1}{2}$	$\frac{1}{3}$
Oak	$6\frac{1}{2}$	$4\frac{1}{2}$	$\frac{2}{3}$	$\frac{1}{2}$

Copper is found in the metallic state or is smelted from ores.

It is red in colour, not easily oxidised, very malleable, and has a greater tensile strength than any metal except wrought iron and steel.

It is used by the builder chiefly for slate nails, bell wires, and

lightning conductors, also for dowels, bolts, and fastenings in positions where iron would be corroded or rusted, and sometimes for covering roofs (see p. 62).

Lead is reduced from ores. It is an extremely soft and plastic metal—very malleable, fusible, heavy, and very wanting in tenacity and elasticity.

It is used for covering flat roofs, for flashings, pipes, bedding girders, etc.

SHEET LEAD is to be purchased in two forms—*cast* or *milled*; both are described according to their superficial weight. Thus 7 lb. lead means lead weighing 7 lbs. per square foot.

Cast Lead is thicker, heavier, and with a harder surface than milled lead, but subject to flaws and sand-holes, and of irregular thickness. It is cast in sheets from 16 to 18 feet long and 6 feet wide.

Milled Lead is rolled out thinner than the other, is more uniform in thickness, bends easily and makes neater work, but is not so durable as cast lead.

The *Weights of Sheet Lead generally used for Roofs* are as follows:—

	lbs. per square foot.	
Aprons and Flashings	5	Thicker if much exposed.
Roofs, Flats, Gutters	6 to 8	
Hips and Ridges	6 or 7	

LEAD PIPES of very large diameter may be made out of sheet lead, but smaller ones should be *drawn*.

Zinc is obtained from ores of the metal. It is easily fusible, malleable when pure, soon destroyed by air containing acid.

It is used by the builder for roof coverings, gutters, cisterns, chimney pots, slate nails, ornaments, and for covering iron (galvanising) to keep it from rusting.

Good sheet zinc is of uniform colour, tough, easily bent backwards and forwards without cracking. The gauges used for roofs are mentioned at p. 62.

Tin is used for lining lead pipes and for small gas tubing. It is very soft, weak, and malleable, and more easily fusible than any other metal.

CHAPTER XIII.

STRESSES IN STRUCTURES.

THIS chapter will give merely the information called for by the Syllabus for the Advanced Course. The subject is fully gone into in Part IV.

The headings in this chapter, marked A to F, are quoted from the Syllabus (see p. vii.), and mention the points required to be understood in the Advanced Course.

Stress and Strain.—When a load or any force acts upon a structure or piece of material, it produces a change of form which is called the *strain*. The internal forces called out in the material to resist this strain are called the *stress*.

Thus a load hanging from a bar of iron lengthens it, causing a *strain*, and calls out in it the resistance of the fibres which are under a tensile *stress*.

These two terms are sometimes used indiscriminately, but it is more accurate to make the above distinction between them.

A. "The Nature of the Stresses to which the different Parts of Simple Structures are subjected."

These stresses are as follows:—

Tension is the stress produced by pulling; it elongates the body upon which it acts, and tends to cause rupture by tearing it asunder.

Thus if a rope or a bar of iron is subjected to a sufficient pulling or tensile stress it will break or tear across.

Compression is the stress produced by pressure; it shortens the body to which it is applied and tends to cause rupture by crushing.

Thus a block of stone bearing a weight is under compression, and if the weight is sufficient it will be crushed.

Transverse Stress is one caused by bending the body on which it acts, and it tends to break it across.

Fig. 422.

Thus the weight in Fig. 422 bends the beam as shown, until, if the weight is sufficiently increased, the beam will break across as in Fig. 423.

Fig. 423.

Shearing Stress is that produced when one part of a body is forcibly pressed or pulled so as to tend to make it slide over another part.

Thus when two plates riveted together as in Fig. 424 are separated

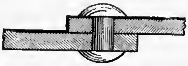


Fig. 424.

Fig. 425.

by pulling (or pushing) in opposite directions one plate slides upon the other and the rivet is sheared as in Fig. 425.

Bearing Stress is that which occurs when one body presses against another so as to tend to produce indentation or cutting.

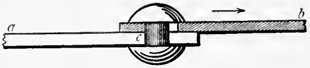


Fig. 426.

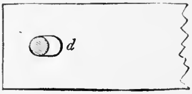


Fig. 427.

In Fig. 426 the plates *a* and *b* being pulled in opposite directions, the rivet *c* being of harder iron than the plate has borne upon it, making the hole larger, as shown at *d*, Fig. 427.

Load.—The load or weight upon a beam may be either concentrated at the centre as in Fig. 428, or uniformly distributed over the whole beam as in Fig. 429.

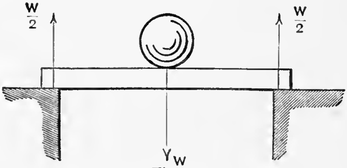


Fig. 428.

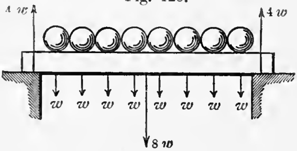


Fig. 429.

There may be concentrated loads at any point or points in the

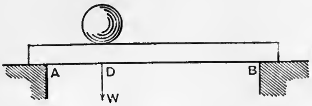


Fig. 430.

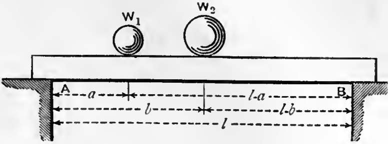


Fig. 431.

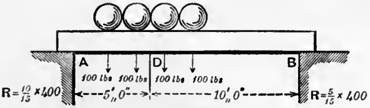


Fig. 432.

length of the beam, as in Figs. 430 and 431;[1] or the load may be uniformly distributed over a portion only of the beam, as in Fig. 432.

Weight of Beam.—In addition to the external loads represented in the figures by W and w, the weight of the beam or girder itself must, when it is large and heavy, be considered.

A Dead Load is one which is very gradually and steadily applied, and which remains steady.

Thus water poured gradually into a tank, supported by a girder, would be a dead load, and so would the tank and the weight of the girder itself.

A Live Load is one which is suddenly applied, as in the case of trains coming suddenly upon a bridge. It is generally taken as equivalent in effect to double its amount of dead load. Thus a live load of 10 tons would produce the same amount of stress as a dead load of 20 tons.

A Mixed Load, consisting partly of live load and partly of dead load, may be reduced to an equivalent amount of dead load by doubling the live load and adding it to the dead load.

Thus, if a structure weighs 500 tons (dead load), and is subject to a live load of 900 tons, the equivalent dead load would be $500 + (2 \times 900) = 2300$ tons.

The Breaking Load for any structure or piece of material is that dead load which will just produce fracture in the structure or material.

The Working or Safe Load is the greatest dead load which the structure or material can safely be permitted to bear in practice.

[1] The small italic letters in Fig. 431 may be ignored for the present. They are explained in Part IV. The numbers in Fig. 432 are explained at p. 267.

The Breaking Stress is that caused by the breaking load; it is sometimes called the *ultimate stress.*

The Working Stress is that caused by the working or safe load; it is sometimes called the **Limiting or Safe Stress.**

It is evident that structures intended to stand must not be subjected to breaking loads or breaking stresses, but only to safe loads and working stresses (see Table, p. 252).

The Factor of Safety is the ratio in which the breaking load or stress exceeds the working load or stress.

That is, it is the figure by which the breaking load or stress is divided to obtain the working load or stress.

Thus if the breaking tensile stress of a bar of iron is 20 tons per square inch, and it is subjected to a working stress of only 5 tons, the factor of safety is $\frac{20}{5} = 4$.

B. "Beams supported at Ends, fixed at one or both Ends, or continuous," and Cantilevers "to know which Parts of the Beam are in Compression and which in Tension."

Supported Beams.

BEAM SUPPORTED AT BOTH ENDS WITH A BREAKING LOAD IN THE CENTRE.—A rectangular wooden beam, supported at the ends, when subjected to a concentrated load greater than it can bear breaks as shown in Fig. 433.

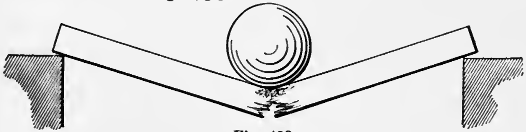


Fig. 433.

The beam bends, sinking most just under the weight, and the fibres of the upper portion of the beam are crushed, and those of the lower portion torn asunder, as shown on a larger scale in Fig. 434.

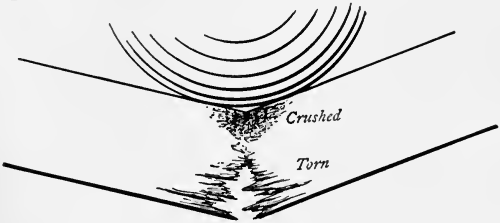


Fig. 434.

Beam supported at both Ends and with a uniformly Distributed Load.—A load uniformly distributed over the beam would produce rupture in the same way, but that the form of the beam before rupture would be slightly different.

A Beam supported at both Ends and subject to a Safe Load—that is, one much smaller than is required to break it—

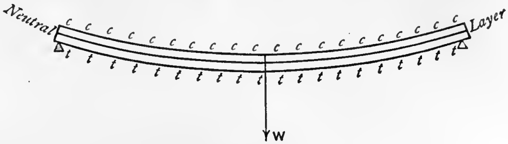


Fig. 435.

will bend to a certain extent, and the fibres of the upper part of the beam will be in compression, and those of the lower part in tension, as shown in Fig. 435. There is a layer between the upper and the lower fibres, in which there is neither compression nor tension, which is called the *neutral layer*.

A Cantilever, however it may be loaded, has the upper fibres in tension and the lower in compression, as shown in Fig. 436.

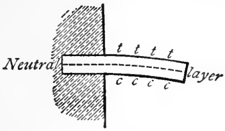


Fig. 436.

Fixed Beams.

A Beam fixed at both Ends—that is, so fixed that the ends cannot tilt up when the beam is loaded—is shown in Fig. 437.

Such a beam is in the condition of two cantilevers, A*f* and B*i*, carrying a beam *fi* between them, which is supported at its ends *f* and *i* by hanging from the ends *f* and *i* of the cantilevers.

From the figure it will be seen that the upper portion of the beam is in tension from A to *f* and from B to *i*; the remainder from *i* to *f* is in compression.

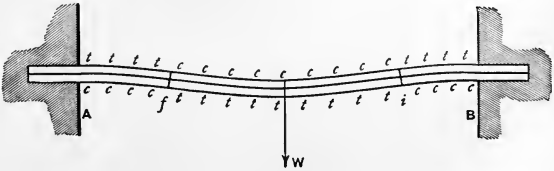


Fig. 437.

The lower portion of the beam is under compression from A to *f* and B to *i*, the central portion *if* being in tension.

It will be noticed that at the points *i* and *f* the nature of the stress in each case changes; *i* and *f* are called the *points of contra-flexure,* and their distances from A and B depend upon the form of section of the beam, and the distribution of the load, etc. Roughly speaking, the points of contraflexure are generally distant about $\frac{1}{4}$ of the span from the abutments.

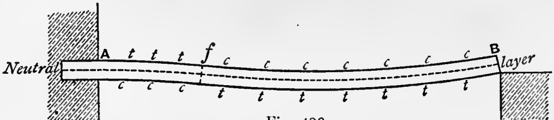


Fig. 438.

A Beam fixed at one End and supported at the other (Fig. 438) is like a combination of a cantilever A*f* and a supported beam *f*B; and the portions in tension and compression respectively are shown by the letters *t t t* and *c c c*.

A continuous Beam is one that extends without break in itself over two or more spans.

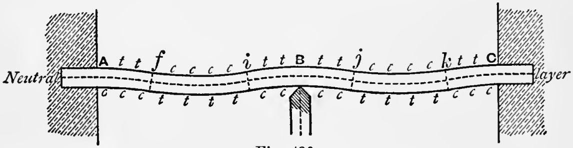


Fig. 439.

If the ends are fixed the compressions and tensions will be as shown by *c c c* and *t t t* in Fig. 439, resembling those of two fixed beams.

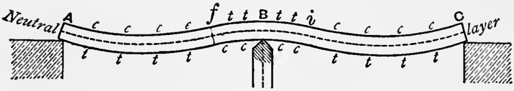


Fig. 440.

If the ends are supported the stresses will be as shown in Fig. 440, the arms in each span being like those of a beam fixed at one end and supported at the other. (Fig. 438.)

C. "Difference in Strength of a Girder carrying a given Load at its Centre or Uniformly Distributed."

On Beams.—A beam that can bear a given load concentrated

at its centre can bear twice that load uniformly distributed over its length.

Thus if the beams in Figs. 428, 429 are similar, and the one in Fig. 428 could bear a concentrated load of 400 lbs., that in Fig. 429 could bear a distributed load of 800 lbs.

On Cantilevers.—Similarly a cantilever that can just bear a given load suspended from its outer end can bear twice that load if it is distributed over its length.

Difference in Strength between Beams of uniform Section supported at both Ends and those fixed at both Ends, or fixed at one End and supported at the other.

A beam fixed at both ends, with a concentrated load at the centre is *twice* as strong as the same beam supported at both ends and similarly loaded.

A beam fixed at both ends, with a uniform load throughout its length is $1\frac{1}{2}$ times as strong as the same beam supported at both ends and similarly loaded.

A beam fixed at one end, and supported at the other, with a concentrated load in the centre is $1\frac{1}{3}$ times as strong as the same beam supported at both ends and similarly loaded.

A beam fixed at one end and supported at the other, with a uniform load throughout its length is of the same strength as the same beam supported at both ends and similarly loaded.

D. "Best Forms for Struts, Ties, and Beams, such as floor joists exposed to transverse Stress."

Best Form for Struts.

Timber Struts should be rectangular in section, and of the same section throughout.

Cast-Iron Struts may be of these cross sections, and tapering in their length, widening from one end to the other as in a column, or from both ends.

Fig. 441.

Fig. 442.

Wrought-Iron Struts are often of these cross sections.

Fig. 443.

Fig. 444.

Fig. 445.

Fig. 446.

Fig. 447.

Fig. 448.

Fig. 449.

Of these *c*, *d*, and *g*, are the best. Fig. 450 is an elevation of *g*, for the other forms the section is uniform throughout the length of the strut; *g* is very useful for struts of roofs.

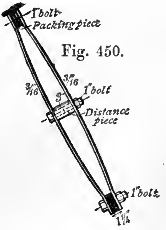


Fig. 450.

Long Struts or Compression Bars are those which are so long in proportion to their width that they fail by bending before crushing.

Short Struts or Compression Bars are those

which do not bend under the load, but fail by actual crushing.

Long Struts fixed at the Ends are much stronger than those of which the ends are hinged or rounded. If both ends are fixed they are 3 times, if one end only is fixed, $1\frac{1}{2}$ times, as strong.

Best Form for Ties.

Any cross section is suitable for a rod or bar in tension whether it be made of timber or wrought iron. Cast iron should never be used for ties.

Best Form for Beams subject to Transverse Stress.

TIMBER BEAMS may be of rectangular cross section uniform throughout their length. The deeper they are the better both for strength and stiffness.

IRON GIRDERS are of a section roughly resembling an I, the upper and lower horizontal portions are called the *flanges*, and the upright portion the *web*.

CAST-IRON BEAMS should have a cross section in which the lower flange to resist tension should have an area from four to six times as great as that of the upper flange which is to resist compression (see Parts I. and IV.)

Fig. 451 shows a section with flanges having areas as 6 to 1, and Fig. 452 with flanges as 4 to 1.

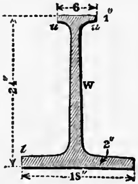


Fig. 451.

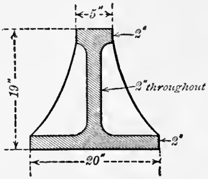


Fig. 452.

And Figs. 453 to 456 show plans and elevations of cast-iron girders for uniformly distributed loads.

Fig. 453.

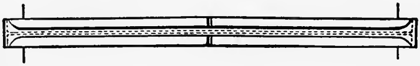


Fig. 454.

The flanges are sometimes made to differ in thickness as in Fig. 451, the web tapering from one to the other, or the metal may be of equal thickness throughout as in Fig. 452.

ELEVATION.

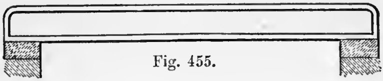


Fig. 455.

PLAN

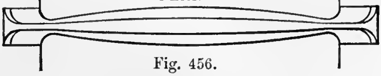


Fig. 456.

Figs. 453, 454, are the elevation and plan of a girder of uniform width, the depth being varied according to the stress to be borne. Figs: 455, 456, are the elevation and plan of a girder of uniform depth, the width of the flanges being varied to suit the stress.

Rolled-Iron Joists are of uniform section like Fig. 457 throughout, the flanges being similar and of equal area.

Fig. 457.

Plate Girders are also of a general I form, built up with a plate and angle irons, riveted together as in Figs. 458-460, or, where additional strength is required, with one or more plates in the flanges (one plate is shown in Fig. 460), and stiffeners to support the web.

Section.

Fig. 458.

Elevation.

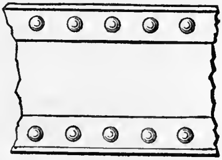


Fig. 459.

Section.

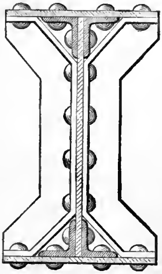


Fig. 460.

E. "In the ordinary kinds of Wooden or Iron Roof Trusses and Framed Structures of a similar description to distinguish the Members in Compression from those in Tension."

There is no very short and simple method for ascertaining

whether the members of a truss are in tension or compression under a given load in any position.

The information can be easily obtained, but the methods employed cannot be explained in these very short notes. They are fully explained in Part IV.

When the loads vary from time to time in position, a member which may with one position of the loads be in tension may with another position of the load have no stress upon it, or even one of an opposite nature.

Thus in an ordinary king-post roof (see Fig. 464) the wind blowing from the right causes a compressive stress upon the strut on that side, but no stress whatever on the other strut, and when the wind is from the left, the stresses on the struts are just reversed.

The student can, however, easily learn and carry in his head the nature of the stresses to which each member of a roof truss is practically subjected.

In Plate IV. and in Figs. 461 to 465, which give a great many forms of roof trusses, each of the members shown in thick lines is in compression, and each of those shown in thin lines is in tension, under all loads that can practically come upon the roof, such as the weight of the roof, of snow lying upon it, and the pressure of the wind upon both sides in turn.

Roofs Generally.

Members in Compression.—Generally speaking all rafters, struts, straining beams, etc., are in compression.

Members in Tension.—All king posts, queen posts, and rods, and all tie beams or tie rods are in tension.

Members under Transverse Stress.—Principal rafters loaded by purlins or roof-covering along their length, between the points at which they are supported, as in Fig. 464, are subject to transverse stress as well as compression, and tie beams carrying ceiling joists are also subject to transverse stress.

TIMBER ROOFS.—Figs. 461 to 465 give skeleton diagrams of ordinary roof trusses (see also Plate IV.)

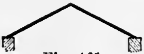


Fig. 461.

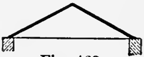


Fig. 462.

Couple Roof (Fig. 461) *and Tied Couple Roof* (Fig. 462).—The rafters are in compression, and the tie in Fig. 462 is in tension.

Fig. 463.

Fig. 463*a*.

Collar Beam Roof.—In this, so long as the walls stand firm (Fig. 463), the beam is a strut and supports the rafters, but if the walls are weak and give way, the beam becomes a tie as shown in Fig. 463*a*.

Fig. 464.

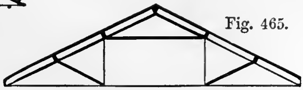


Fig. 465.

King-Post Roof and Queen-Post Roof (Figs. 464, 465).—Nothing need be said about these, except that in Fig. 464 the principal rafters being loaded by the roof-covering between their points of support are subject to transverse stress, as well as the compression upon them, and the tie beam being loaded by the ceiling is also subject to transverse stress as well as tension.

When the purlins are only at the points at which the principal rafter is supported, as in Fig. 465, it is not subject to transverse stress, nor is the tie beam, where there is no ceiling.

Other Framed Structures.

Trussed Beams.—The diagrams, Figs. 466, 467, show by thick lines the members in compression, and in thin lines the members in tension in trussed beams (see Parts I. and IV.)

Fig. 466.

Fig. 467.

These will be the same in nature though not in amount, whether the load be distributed along the upper surface or concentrated at points.

When the load is distributed between the points where the bracing joins the upper beam, the latter is of course subject to transverse stress as well as to compression.

Warren girder.

Fig. 468.

Lattice girder.

Fig. 469.

N. girder.[1]
Fig. 470.

Cross braced N. girder.[1]
Fig. 471.

Braced Girders.—Figs. 468 to 471 are common forms of braced girders, and they show by thick lines the members in compression, and by thin lines the members in tension, when the girders are carrying loads uniformly distributed along the lower flange or at the points where the braces join that flange.

The stresses will be similar in character when the load is on the upper flange, but in Fig. 470 an additional bar will have to be introduced as dotted, and it will be in compression.

Such girders are frequently suspended between their abutments from the ends of their upper flanges; in such a case the construction at the ends of the girder is slightly different, but the nature of the stresses is practically the same as shown in the Figures.

F. "In the case of a concentrated or uniform load upon any part of a beam supported at both ends to ascertain the proportion of the load transmitted to each point of support."

Concentrated Load in Centre of Beam.—If a concentrated

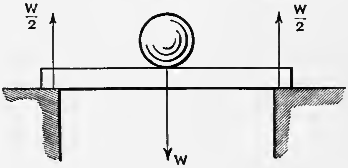


Fig. 472.

weight W be placed upon the centre of a beam supported at the ends, then half the weight is borne at each end. Thus in Fig. 472 half the weight W is borne on each abutment.

Load uniformly distributed over whole Length of Beam.—If a load, 8 w etc., Fig. 473, is uniformly distributed over a

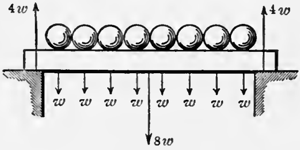


Fig. 473.

[1] Sometimes called *Whipple-Murphy* girder.

beam, then again half the load (in this case 4 w) is borne by each abutment.

WEIGHT OF THE BEAM ITSELF.—The weight of the beam itself is like a uniform load, and half that weight is supported by each abutment.

LOAD AT ANY POINT OF BEAM.—The proportion of the load borne by each support may, avoiding formulas, be found by the following rule.

RULE.—*If a load is placed anywhere on a beam supported at both ends, then the proportion of the load borne by either support is equal to the load, multiplied by the distance from its centre of gravity to the other support, and divided by the length of the beam between the supports.*

CONCENTRATED LOAD.—Thus in Fig. 474 the load W is 400 lbs., and it is distant 5′ 0″ from A and 10′ 0″ from B.

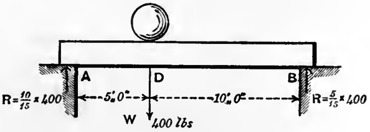


Fig. 474.

$$\text{The proportion of W borne at A is equal to } \frac{\text{W} \times \text{distance DB}}{\text{Length AB}},$$

$$i.e. = \frac{400 \text{ lbs.} \times 10 \text{ feet}}{15 \text{ feet}} = 266\tfrac{2}{3} \text{ lbs.}$$

$$\text{The proportion of W borne at B is equal to } \frac{\text{W} \times \text{distance DA}}{\text{Length AB}},$$

$$i.e. = \frac{400 \text{ lbs.} \times 5 \text{ feet}}{15 \text{ feet}} = 133\tfrac{1}{3} \text{ lbs.}$$

Reaction.—The proportion of the load borne by each support is called the reaction at that support. In Fig. 474 the reaction at A is shown as $R = \frac{10}{15} \times 400$. Reaction at B, $R = \frac{5}{15} \times 400$.

LOAD UNIFORMLY DISTRIBUTED OVER CENTRAL PART OF THE LENGTH OF A BEAM.—In this case the load may be considered as acting through its centre of gravity, and then its reactions are found as in the case of a concentrated load at the centre.

Thus if the load were uniformly spread over an equal distance on each side of the centre of the beam as in Fig. 475, then half the load is borne by each support.

Similarly when the uniform load is made up of a number of weights 4 w, then each support takes 2 w.

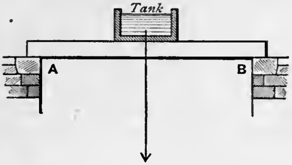


Fig. 475.

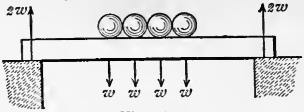


Fig. 476.

LOAD UNIFORMLY DISTRIBUTED OVER ANY PART OF THE LENGTH OF A BEAM.

In this case the load is equivalent to a single concentrated load at the centre of gravity of the distributed load.

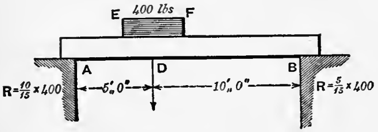


Fig. 477.

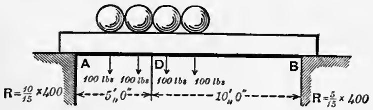


Fig. 478.

Thus in Fig. 477 the weight of the tank which is distributed over E F may be taken as acting at D through its centre of gravity.

The reactions are then just the same as in the case illustrated in Fig. 474.

Again when the distributed load is made up of separate weights as in Fig. 478, they may be considered as acting through their common centre of gravity, and the reactions are again the same as shown in the Fig. 474.

ANY NUMBER OF CONCENTRATED LOADS ON A BEAM.—When the loads are unequal, and placed unsymmetrically, the reaction of each at each support is found in turn. The total reaction at either support will be the sum of the reactions produced by each weight at that support.

Take a simple case, with only two unequal weights placed unsymmetrically, as shown in Fig.

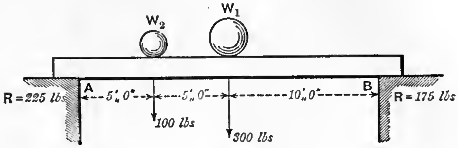


Fig. 479.

Applying the rule given above for a single weight not in the centre of the beam, we have—

	at A	at B
Reaction produced by W_1	$\frac{10}{20} W_1 = \frac{10}{20} . 300 = 150$	$\frac{10}{20} W_1 = \frac{10}{20} . 300 = 150$
" " W_2	$\frac{15}{20} W_2 = \frac{15}{20} . 100 = 75$	$\frac{5}{20} W_2 = \frac{5}{20} . 100 = 25$
Total reaction produced by $W_1 + W_2$, *i.e.* by 300 + 100 lbs.	225 lbs.	175 lbs.

N.B.—*The consideration of bending moments, moments of resistance, shearing stresses, etc., and calculations for strength, even for the simplest beams, does not form a part of this Course but is entered upon in Part IV.*

APPENDIX.

EXAMINATION PAPERS SET IN THE YEARS 1888, 1889, 1890 BY THE SCIENCE AND ART DEPARTMENT, SOUTH KENSINGTON

IN

BUILDING CONSTRUCTION.

Second Stage or Advanced Course.

General Instructions.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary or the Advanced or the Honours paper, but you must confine yourself to one of them.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

All drawings must show a correct knowledge of construction. Neat and accurate drawing to scale is required. Where only sketches are asked for the proportions must be approximately correct, though extreme accuracy, as in drawings to scale, is not necessary. The drawings may be left in pencil, provided they are distinct and neat. No extra marks will be allowed for inking in.

You are to confine your answers *strictly* to the questions proposed.

Put the number of the question before your answer.

Answers in writing must be as short and clearly stated as possible, and close to any figures to which they may refer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

A single accent (′) signifies *feet* ; a double accent (″) *inches.*

Questions marked (*) have accompanying diagrams.

The Examination in this subject lasts for four hours.

1888.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.
You are only permitted to attempt *six* questions.

---

21. Explain the meaning of "hydraulic lime," and how you would practically test a specimen of limestone in order to ascertain whether it would produce an hydraulic lime. (12.)

22. Describe the difference in both the behaviour and appearance of similar bars of cast and wrought iron—
    (*a*) When broken under a tensile stress suddenly applied.
    (*b*) When broken under a slowly applied tensile stress. (12.)

*23. Plans of two successive courses at the end of a brick wall built in English bond.
Draw, to a scale of $\frac{3}{4}''$ to a foot, showing the use of diagonal bond in both courses, to strengthen the wall. (12.)

*24. Elevation of a beam loaded with 15 tons at a point out of the centre.
What proportion of the weight is borne at each of the two supports, A, B?
What portion of the beam is in tension, and which in compression? (14.)

*25. Line diagram of a girder constructed for a uniform load, as shown.
Draw to twice the size, showing the members in tension by single, those in compression by double, and those under compression and bending stress by triple lines; the stresses due to their own weight to be neglected.
Draw a similar diagram, supposing the same load to be along the bottom instead of the top of the girder, omitting any bars you consider superfluous, and making any other alterations you think necessary. (14.)

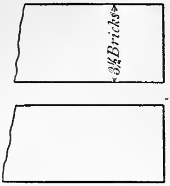
*26. Section of part of a single floor with common joists $9'' \times 2\frac{1}{2}''$.
Draw, to a scale of $\frac{1}{6}$, a sectional elevation through AA, showing the five floor battens, and four ordinary methods of forming a tight joint between them. (14.)

27. Draw, to a scale of $1\frac{1}{4}''$ to a foot, a cross section of a double-faced moulded skirting, 15″ high, tongued to floor, and secured to wood grounds plugged to a brick wall. (16.)

*28. Line diagram of part of an iron roof truss for a 38 feet span, the rise being $\frac{1}{4}$ the span, and the camber of tie rod $\frac{1}{30}$ the span.
Draw a line diagram of the complete truss, to a scale of $\frac{1}{96}$.
Give an elevation of the joint at A, $\frac{1}{2}$ full size, with any details required to fully explain its construction, *aa* being angle irons $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$; and *bb* (not continuous), as well as *c*, to be of $1\frac{1}{4}''$ round iron. (16.)

*29. Plan of part of the top of a wall at the angle of a building, showing the wallplates to carry a hipped roof.
Draw, to a scale of $\frac{3}{4}''$ to a foot, adding an angle tie and dragon

(23)



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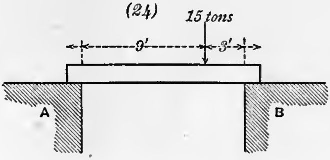

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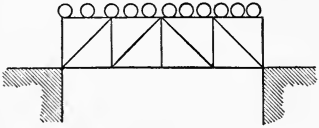

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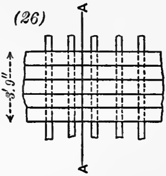

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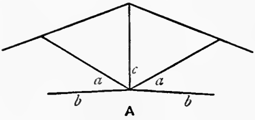

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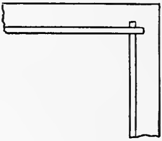

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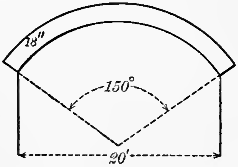
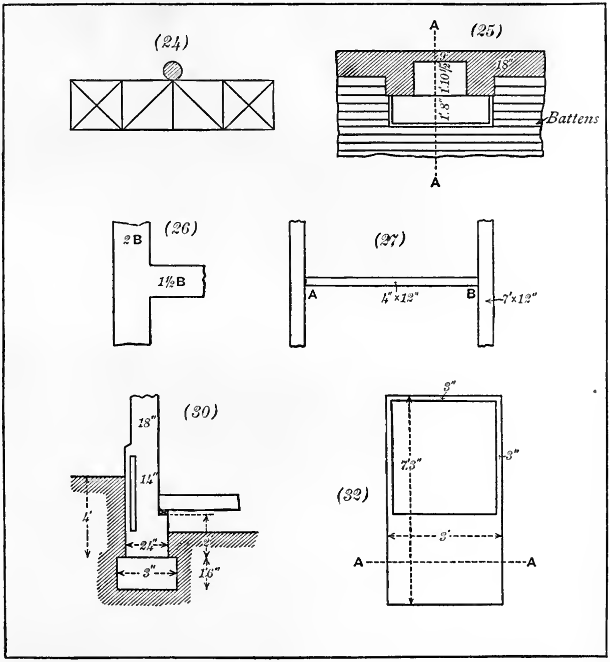



(24)
(25)
A
A
18"
1'.10½"
1'.8"
Battens
(26)
2 B
1½ B
(27)
A
4" × 12"
B
7' × 12"
(30)
18"
14"
4'
24"
3"
1'6"
(32)
3"
3"
7'3"
3'
A
A

beam. Give a vertical section through the dragon beam, showing its connection with the angle tie and the foot of the hip rafter. (16.)

30. Two iron plates $10'' \times \frac{1}{2}''$ are to be connected by a riveted lap joint.
Draw, $\frac{1}{4}$ full size, a plan of a double riveted joint, the rivets being $\frac{3}{4}''$, with a pitch of $2\frac{1}{2}''$.
Show by another plan a similar joint, but with the rivets arranged so as to weaken the plates as little as possible. (17.)

*31. Elevation of a brick archway.
Draw, to a scale of $\frac{1}{48}$, showing the centering you would use in its construction. Full details to be given, with the scantlings, including supports. (17.)

32. Give a horizontal section, to a scale of $1\frac{1}{2}''$ to a foot, through a cased window frame for $2\frac{1}{4}''$ double hung sashes; the wall being of stone, $24''$ thick, finished inside with lath and plaster on battens, and square boxed shutters for a 4 feet opening. (18.)

1889.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.
You are only permitted to attempt *six* questions.

---

21. Describe the following bricks, stating the purposes for which they are suitable :—Shippers, grizzles, malm cutters, blue Staffords. (12.)

22. What is the composition of the following stones; which would you consider the most durable, and why?
York stone, Bath stone, Craigleith stone. (12.)

23. Explain what is meant by rich lime, poor lime, stone lime.
Which will carry the most sand, and why? (12.)

*24. Diagram of a loaded truss.
Draw, to double the size, omitting as many members as possible, and marking with a × all the remaining members brought into compression by the load. (14.)

*25. Plan of a fireplace in a ground-floor room.
Draw, to a scale of $\frac{1}{24}$, a section through A—A, showing all the detail of the construction. (14.)

*26. Plan showing the junction of a $1\frac{1}{2}$-brick wall built in Flemish bond with a 2-brick wall built in English bond.
Show, to a scale of $\frac{3}{4}''$ to a foot, the arrangement of the bricks in two successive courses. (14.)

*27. Plan of a cross-beam framed into two girders.
Draw, to a scale of $1\frac{1}{2}''$ to a foot, sections through the joints, showing at A a shouldered or tusk-tenoned joint, and at B a chase-mortised joint.
Under what circumstances would the latter joint be used? (16.)

28. Give a part elevation and a cross section of a plate girder 2 feet deep, with a $\frac{1}{4}''$ web, connected to flanges, each consisting of two $12'' \times \frac{3}{8}''$ plates; the rivets to be $\frac{3}{4}''$ diameter, with a pitch of $4''$. (16.)

29. Draw, to a scale of 3 feet to an inch, an elevation of about half of a wooden roof truss for a 34 feet span, containing the following members:—
Tie-beam, $10'' \times 5''$.
Queen posts, $5'' \times 3\frac{1}{2}''$.
Principals, $5'' \times 5''$.
Straining beam, $5'' \times 6''$.
Braces, $4'' \times 2\frac{1}{2}''$. (16.)

*30. Vertical section through the base of the outer wall of a brick dwelling-house built on a damp site.
Draw, to a scale of $\frac{1}{2}''$ to a foot, showing the joints of the brick-work, and making any alterations or additions you consider necessary to prevent the damp from affecting the walls. (17.)

31. Give a cross section, to a scale of 1″ to a foot, through the ridge of a slated roof, showing three courses of Duchess slates centre nailed on $3'' \times 1''$ battens, with $4'' \times 2''$ rafters, and a $9'' \times 1\frac{1}{2}'$ ridge-piece finished with slate ridging.
Also give a similar section showing the details of a lead ridge roll. (17.)

*32. Elevation of a 2″ door, glazed above with nine panes and two panels below, bead flush outside and moulded inside.
Draw, to a scale of $\frac{3}{4}''$ to a foot, the outside elevation; also a section through A—A, to double the scale. (18.)

May and June 1890.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.
You are only permitted to attempt *six* questions.

---

21. What is the difference between single and double laths, and what does the first coat of plaster on ceilings ordinarily consist of? (12.)

22. When ought timber to be felled, and why?
What is American yellow pine chiefly used for? (12.)

*23. Sketches of two forms of mortar joints, one being known as *tuck pointing.*
Draw them to twice the scale, giving each its proper name, and state your views as to their merits, also making any alteration you think advisable. (12.)

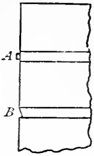
*24. Cross section through part of a brick wall faced with ashlar.
Draw, to a scale of 1″ to a foot, showing its construction. (14.)

25. Explain by sketches the meaning of the following terms:—"fascia and soffit boarding to eaves," "dragging tie or dragon beam," "flitched girder," "torus moulded skirting." (14.)

26. Give an elevation and longitudinal section, one half full size, of each of the following joints in a $1\frac{1}{2}$-inch lead pipe:—a wiped joint, a blown joint. (14.)

*27. Cross section of a hollow brick wall resting on a concrete foundation.

(23)



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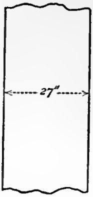

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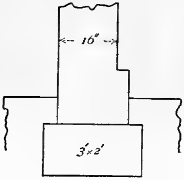

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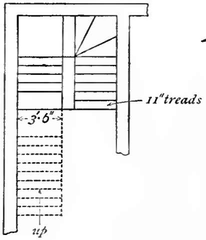

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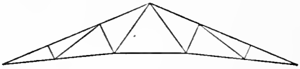

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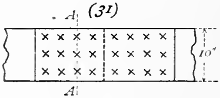

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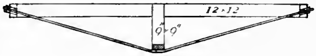

Draw, to a scale of $\frac{3}{4}''$ to a foot, showing the hollow space next the outer face, iron wall ties, and an asphalte damp course. (16.)

*28. Plan of a stair.

Draw, to a scale of $\frac{1}{4}''$ to a foot, showing the handrail by double lines, and newels; also giving the name by which it is known and the names of its different parts.

Give, to a scale of $1\frac{1}{2}''$ to a foot, an end elevation of two of its steps, showing return moulded nosings and a sunk and moulded string. (16.)

*29. Line diagram of an iron roof truss.

Draw to twice the scale, showing the members in tension by single lines and those in compression by double lines. (16.)

30. Elevation of a beam of a traveller running on a gantry.

Give an end elevation of the traveller, to a scale of $\frac{1}{2}''$ to a foot, showing how it is carried on the gantry. (17.)

*31. Plan of a double cover riveted joint in a $\frac{3}{4}''$ tie bar, showing the positions of the rivets.

State the nature of the joint, having regard to the arrangement of the rivets; and draw a section, one-third full size, through AA, showing $\frac{3}{4}''$ rivets to a $3''$ pitch, with snap heads above and pan heads below. (17.)

32. Draw, to a scale one-sixth full size, a vertical section through a window back, showing a coursed rubble wall $12''$ thick, with both stone and wood sills, and the bottom rail of a $2\frac{1}{4}''$ double hung sash. The back lining to be $3'$ high to sash, with moulded panels, and to be box-framed, showing vertical sliding shutters in two $3'\ 6''$ leaves. (18.)

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